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THESIS

THE ANALYSIS AND DESIGN OF MICROCOMPUTER BASED LOCAL AREA NETWORKS FOR THE PUBLIC WORKS DEPARTMENTS OF NAVAL FACILITIES COMMANDS

by

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March, 1990

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The purpose of this thesis is, through the application of both academic theory and practical procedures, to present a manual which outlines a step wise procedure for the analysis and design of a microcomputer based Local Area Network for the Public Works Departments of Naval Facilities Commands. A brief overview of the Public Works structure and operations is conducted. Analysis and design objectives, along with a methodology for achieving these objectives are tendered. Finally, a review of the essential parts of the Requirements Evaluation Report is presented.

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The Analysis and Design of Microcomputer
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Public Works Departments of Naval Facilities Commands

by

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Captain, United States Marine Corps
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Submitted in partial fulfillment
of the requirements for the degree of

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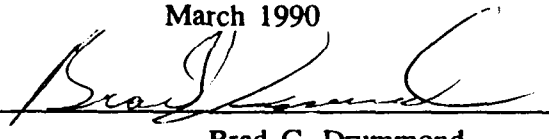
Author: 

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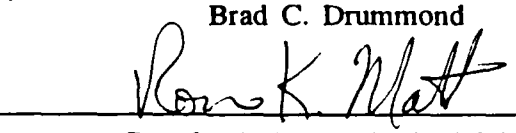
Approved by: 

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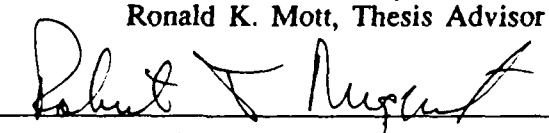

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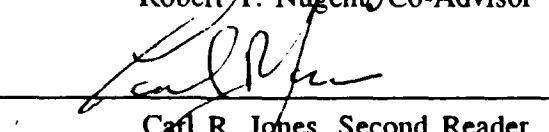

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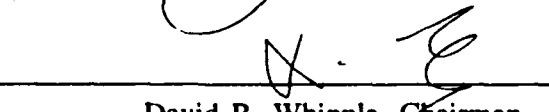

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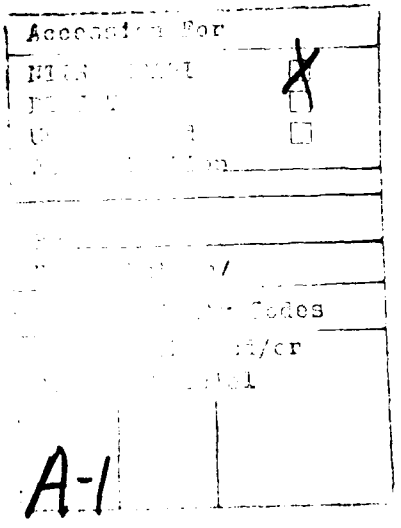
ABSTRACT

The purpose of this thesis is, through the application of both academic theory and practical procedures, to present a manual which outlines a step wise procedure for the analysis and design of a microcomputer based Local Area Network for the Public Works Departments of Naval Facilities Commands. A brief overview of the Public Works structure and operations is conducted. Analysis and design objectives, along with a methodology for achieving these objectives are tendered. Finally, a review of the essential parts of the Requirements Evaluation Report is presented.



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I. INTRODUCTION

A. CONCEPT

> ...the integrity and compatibility of information are the big issues. The automated office requires timeliness and friendliness. In the office, the Local Area Network can give users fast and efficient access to a common pool of information including customer lists, supplier lists, schedules, and document formats. [Ref. 1:p. C11-010-107]

Due to the accelerated rate at which the computer industry changes, Local Area Networks in particular, it is necessary to provide a definition of the technology. For the purposes for this study a Local Area Network (LAN) can be defined as follows; A system for the interconnection of two or more communicating devices that are:

- Intra-organization
- User administered
- Structured - that is, integrated into a discrete physical entity and interconnected by a continuous structural medium
- Limited in geographical scope
- Supportive of full connectivity - so that every user device on the network is potentially capable of communicating with every other device
- Commercially available [Ref. 1:p. C11-010-106]

The concept of this study is, through the application of both academic and practical procedures, to develop a comprehensive guide for establishing a microcomputer based LAN and to stimulate interest for further pedagogical study in this arena.

The basic analysis and design concepts and procedures presented are not oriented specifically towards the thesis topic and, as such, are germane to any organization undergoing a similar transition.

B. BACKGROUND

The Western Division (WESTDIV), Naval Facilities Engineering Command "provides the Naval Shore Establishment with public works guidance, develops management systems, and provides contract support for facilities related functions". [Ref. 2:p. 1-2] These services include "establishing standards and procedures for specialized administrative and technical functions". [Ref. 3:p. 2-2] As of the completion date of this study, the Public Works Management Automation (PWMA) on the west coast from Adak, Alaska to San Diego, California is one of WESTDIV's primary interests.

PWMA is presently a super-set of Base Engineering Support, Technical (BEST) Maintenance Control Subsystem. The hardware used by the BEST subsystem, the Honeywell DPS/6 minicomputer, was centrally procured by the Naval Facilities Command (NAVFAC). Installation of the BEST application software modules was provided by the Naval Facilities Engineering Field Divisions (EFDs). Additionally, the EFDs provide ongoing technical and maintenance support.

The increased number of BEST system users and large databases has resulted in a degradation of the system response time. According to NAVFAC ltr 5200 16b of 6 Mar 89, to solve this problem, "There is an increasing interest by activities in converting to networked microcomputer systems as opposed to minicomputer upgrades." The letter continues, "Given limited resources and potential pay-back of investment, NAVFAC has opted not to sponsor an open ended delivery order contract for system (Honeywell) upgrades." In response to this decision WESTDIV is providing the analysis and design criteria to replace all the Honeywell minicomputers with microcomputer based LANs. The BEST application programs presently reside on the Honeywell DPS/6, but are in the process of being converted to run on IBM compatible microcomputer based LANs. To facilitate a smooth transition from one hardware platform to the next, a logical, comprehensive yet simple procedure must be developed. In response to this need, this study was undertaken.

C. PURPOSE

The primary purpose of this thesis is the application of academic theory to create a manual which outlines a step wise procedure for the analysis and design of a microcomputer based Local Area Network for the Public Works Departments of Naval Facilities Commands. The manual will be utilized by the Western

Division, Naval Facilities Engineering Command, San Bruno, California as a guide for Local Area Network planning throughout the Western Division.

D. PROCESS OVERVIEW

The WESTDIV Local Area Network Assistance Visit will last a period of two working weeks and be divided into two phases: the Analysis Phase and the Design Phase. Analysis is the "separating or breaking up of any whole into its parts, with an examination of these parts to find out their nature, proportion, function, interrelationship, etc." [Ref. 4] During the analysis phase, which is normally completed in week one, the primary concern is to become familiar with the current systems, identify feasible alternatives, solve existing problems, and exploit opportunities.

Design is the creation of preliminary sketches or arrangement of plans for the purpose of achieving a desired goal. [Ref. 4] During the Design Phase, week two, various ways of physically implementing alternatives illuminated in the Analysis Phase are evaluated. The most feasible alternative is selected and the requisite hardware and software configurations are formulated.

The evaluation team will be composed of two industrial engineers from WESTDIV (code 1615). As will become evident, to

complete the survey effectively within the prescribed time, the team must be composed of two members.

At the conclusion of the two week period the evaluation team will present a PWMA Requirements Evaluation including research methodology, findings, component and design recommendations, and hardware and software specifications.

E. SCOPE

To define the scope of this thesis certain limitations were imposed. These restrictions were dictated by WESTDIV to ensure the proper utility of the finished product. The first limiting factor is an assumption. It is assumed that the primary users of this study will be engineers at WESTDIV who possess a fundamental knowledge of the concepts of engineering and data communications. Making this assumption eliminates the need to clutter the document with rudimentary information thus obscuring the primary purpose. Secondly, the thesis will not provide an in-depth presentation of the Public Works Department as an organization. However, certain basic Public Works Department (PWD) characteristics will be illuminated to ensure the utility of the study to the average person. This limitation was imposed for the same reason stated above.

The third stipulation is the thesis will address automation requirements of a PWD with the understanding that a particular

collection of hardware and software has been specified and will be supported by WESTDIV. As a result, the thesis will not attempt to compare or contrast various hardware and software products to ascertain the optimal solution. Instead, it will provide explicit guidance on which combinations will best meet the needs of a particular PWD based on the equipment specifications proposed by WESTDIV.

Finally, because the need for a microcomputer based LAN is highly dependent on the specific activity, and not a function of the WESTDIV Local Area Network Assistance Visit, a method of LAN justification will not be investigated. Further study in this area, at a later date, in conjunction with the actual procurement process of the pre-designed system is recommended.

F. RESEARCH METHODOLOGY

The methodology employed involved both research and actual hands-on evaluation. Initial research was conducted in the areas of Public Works Departments, the psychology of organizational change, organizational introduction to LANs, and LAN management. Next, a case study of the Naval Postgraduate School PWD was performed. During the case study interviews with all key players were conducted and questionnaires were distributed to all of the players. Subsequently, in-depth research was conducted in the areas of LAN hardware, LAN software, and inter-connectivity.

Following this study, several trips to WESTDIV to scrutinize their LAN provided an opportunity to gain hands on experience. Throughout this process, two industrial engineers from WESTDIV, Ron K. Mott and Robert T. Nugent, acted as consultants providing guidance when necessary. The use of these various information gathering techniques and sources ensured pertinent information elements were not inadvertently omitted.

The next section of this chapter provides a basic introduction to Public Works, its mission, organizational structure and functional breakdown. Additionally, the organizational environment, internal and external, including the information flow and associated typical pitfalls are addressed. The section provides the PWD novice with the necessary knowledge base to glean the desired information from this study. Readers already familiar with the basics of PW are advised to go directly to section H omitting the next section.

G. PUBLIC WORKS DEPARTMENTS

> The sole purpose of a public works organization is to provide quality products and services in a cost efficient and responsive fashion to those commands supported. The extent to which this is accomplished provides a direct measure of the effectiveness of a PWD. [Ref. 2:p. 2-1]

1. Organization and Mission

Public Works Departments are service organizations which provide a broad range of technical support and professional

services to fleet and shore commands. Some of the primary functions are:

- Facilities planning, maintenance, repair, minor construction, alteration, and equipment installation
- Real Estate management
- Utilities system operation and maintenance
- Family Housing Administration
- Facility disposal
- Transportation management, operations and maintenance

The span of control, organizational structure, and political environment are highly dependent upon such factors as size, scope, location, and mission of a particular PWD. As a result, the information to follow will be general in nature and necessarily have to be tailored to fit a specific site.

Span of control refers to the number of subordinates a superior can effectively manage. The span should be broad enough so as to prevent excessive fragmentation of the organization and yet narrow enough so a manager can maintain complete control. In this regard, the Navy's Position Program Management, as directed by SECNAVINST 5310.11, states top level managers should be responsible for at least three middle managers. While Middle managers can supervise ten or more workers, if the tasks required of the workers are well documented and little management is required. "Deviation from this policy should be critically reviewed when planning or reviewing PWD organizations." [Ref. 2:p. 2-1]

The basic organizational structure for a PWD is shown in Figure 1.1. [Ref. 2:p. 2-2 fig. 2-1] The organization is headed by the Public Works Officer (PWO).

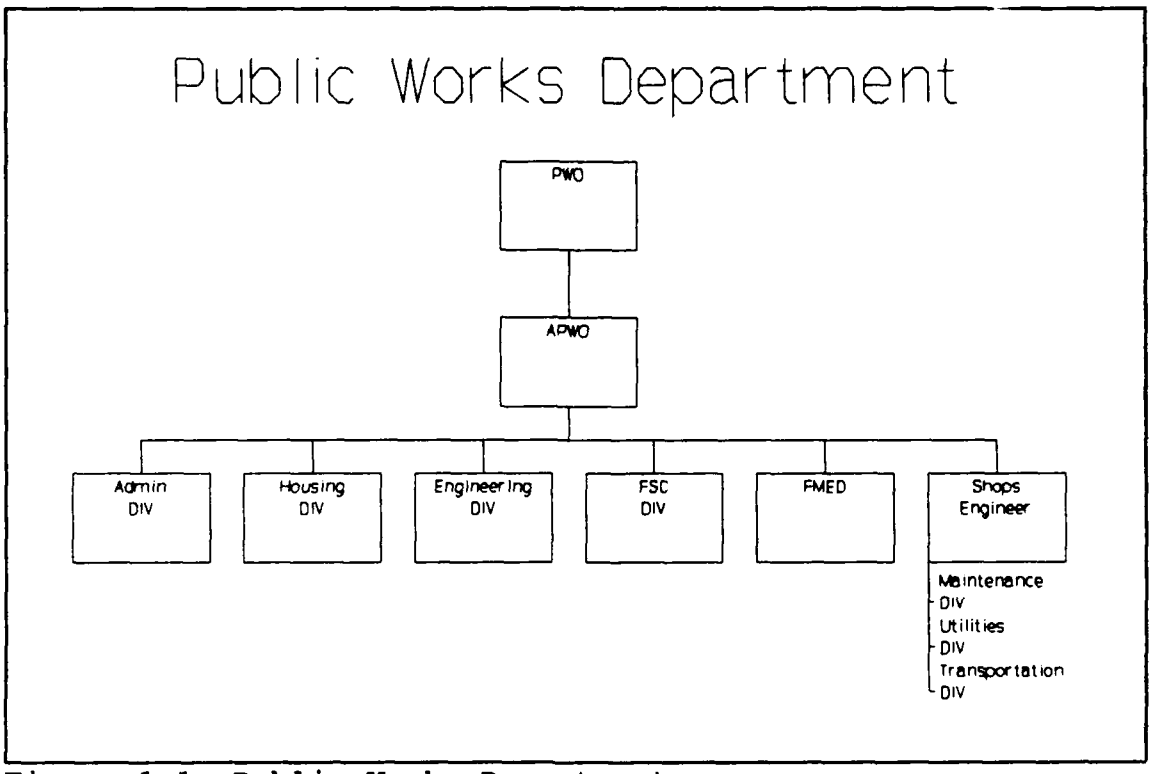


Figure 1.1 Public Works Department

The PWO is usually a Civil Engineer Corps Officer (CEC) and is responsible to the Commanding Officer for the PWD organization, operations, administration, and supervision. He is also responsible for planning, design, construction, maintenance, and repair of shore facilities. Additionally, safety certifications and environmental considerations fall to the PWO.

The PWO is aided by the Assistant Public Works Officer (APWO) who is also normally a CEC. The APWO acts in the absence of the PWO, but is normally responsible to the PWO for the day-to-day operation of the department.

a. Functional Areas

There are two functional areas in the organization the Administrative and Technical, and the Production.

(1) Administrative and Technical. The Administrative and Technical area is broken into five divisions. The Administrative Division provides administrative, personnel, financial and managerial support to the department.

The Family Housing Division is responsible to all managerial aspects of family housing. These duties include planning, operation, maintenance, repairs, utilization, and inspection of housing facilities.

The Engineering Division provides engineering services to include facilities planning, production support, and engineering studies. Studies are conducted in such areas as utility optimization, environmental protection and project design.

The Facilities Management Engineer Division (FMED) controls, coordinates, and evaluates all real property maintenance actions. This division has been purposely separated from the production area to allow for increased management

control. FMED responsibilities include; facilities inspection, annual and long range maintenance plans, monitor all work requests, prepare job estimates, prepare shop load plans, identify and monitor contract jobs, quality assurance, and the evaluation of in-house work performance.

The Facilities Support Contracts (FSC) Division administers external contracts awarded by NAVFACENGCOM. These are primarily maintenance service and maintenance construction contracts.

(2) Production. The divisions that fall in the Production area, Maintenance, Utilities, and Transportation, are responsible for all the work performed by government employees. Additionally, they provide assistance in developing contracts and functional advice for contract support. The Shops Engineer organizes, controls and coordinates the production divisions on a daily basis and reports to the APWO.

The Maintenance Division is responsible for performing preventative maintenance inspections (PMI), emergency service work, facilities maintenance and minor construction. They also provide solid waste collection, pest control, and caretaking services.

The Utilities Division is responsible for operating utilities plants and distribution systems, monitoring these plants and systems and performing utilities inspections.

This includes planning, managing and operating Navy owned utilities, coordinating with local utility companies, promoting utility conservation, and developing utility casualty procedures.

The Transportation Division provides transportation services to the entire PWD. Responsibilities entail; operating vehicle and equipment pools, operating passenger and freight transportation systems, providing heavy lift and utility vehicles, and testing and licensing vehicle operators.

These are the basic internal working elements of a PWD. The following paragraphs will investigate the organizational environment in which these basic elements must operate.

2. **Organizational Environment**

When viewing a particular PWD for the purposes implementing any type of change it is always important to assess the organizational environment. An organization's environment can be subdivided into the internal and external conditions.

a. External Environment

> In our time the external environment has undergone rapid changes that have far reaching effects on organizations and their management strategies. The ups and downs of the economy, the changing attitudes of customers, the requirements of government agencies, the inflated costs of energy, materials, and labor--all these affect the organization and its management. Indeed, an organization's responsiveness to its environment may be critical to its survival. [Ref. 5:p. 53]

Although the details on how the PWD interacts with its external environment are beyond the scope of this study, it is important to grasp the fundamental relationship the PWD has with the Supply Department (SUPDEP) and the Comptroller (COMPT).

Twenty percent of the requisitions processed by the SUPDEP are attributable to the PWD.[1] As a result, the smooth interaction between the Supply Department and the PWD is essential for a naval base to operate effectively. The supplies required by the PWD to accomplish jobs are ordered through the SUPDEP. When the supplies are received it is the SUPDEP responsibility to inform the PWD. The PW division controlling this process is the FMED (see Figure 1.2). In many cases, a breakdown in communications occurs in this sequence resulting in inefficiencies. The exact disconnects and problems will not be discussed. This link is critical and must be carefully managed by both departments and taken into consideration by the analyst during the procedure detailed in the following chapters.

The interface between the COMPT and the PWD is the second critical link. On the average naval facility, approximately eighteen percent of the Direct Budget, including

[1] This information was gleaned from Naval Postgraduate School Supply Department's Standard Automated Contracting System (SACONS). It is assumed that this figure does not greatly deviate from the "average naval facility".

reimbursables, is consumed by the PWD.[2] [Ref. 6] This fact alone, due to the recent budget restriction and subsequent command attention, makes it paramount that the funds allocated to the PWD are utilized effectively and efficiently. As depicted in

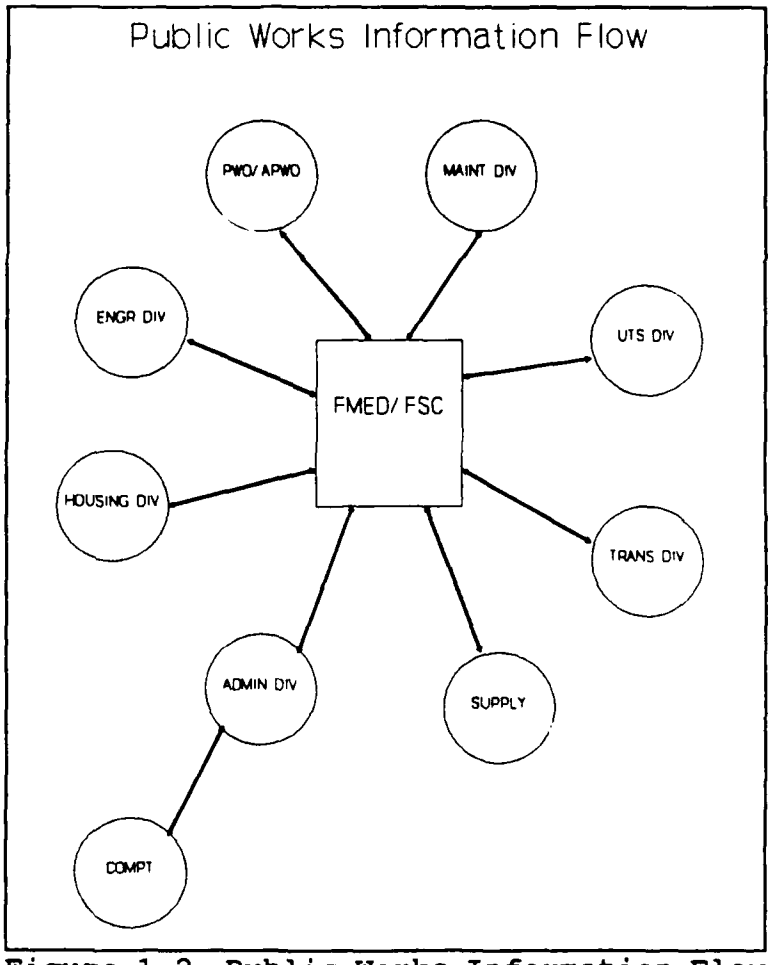


Figure 1.2 Public Works Information Flow

[2] This information was gleaned from Naval Postgraduate School OP-32 Congressional Budget Exhibits submitted 29 Jun 88 revised 27 Oct 89. It is assumed that this figure does not greatly deviate from the "average naval facility".

Figure 1.2, the Administrative division, through input from the FMED, monitors the receipt and expenditure of funds. Failure at this connection can have a severe budgetary impact.

These two crucial links, SUPDEP and COMPT, are the keys to the PWD interacting successfully with their external environment. In order for the proper communication to exist to facilitate the desired linkage it is necessary for the PWD to operate correctly from within.

b. Internal Environment

An organization's internal environment is defined as, "...everything within the organization, including its workers, managers, working conditions, and culture." [Ref. 5:p. 691] One of the most important internal environmental elements is the formal communications and the associated work flow utilized by the workers and managers to complete the assigned mission. The entire PW mechanism depends upon the proper processing of job order numbers.

Job order numbers are processed in the following manner. Referring to Figure 1.2, all work requests should be funnelled through the FMED. The FMED then generates a job order number for each work request. The necessary supply and accounting data are attached and the job order number is distributed to the proper division for execution. This job order

number is utilized to track all aspects of the work request, from commencement to completion. Upon completion of the task, the job order number is returned to FMED where the PW, supply, and accounting records are updated. Utilized correctly this system allows the PWD to not only effectively complete their primary mission, but also provide the external environment with the requisite data.

Based on observations during the case study, unfortunately and all to often, the system is circumvented by the use of informal communication. "Informal communication is, the grapevine, or any communication within the organization that is not officially sanctioned...and it shows admirable disregard for rank or authority and may link organization members in any combination of directions." [Ref. 5:p. 691 and 516] Typically, the breakdown begins when work requests are not initially funnelled through the FMED and, as a result, job order numbers are not created prior to the commencement of work on a particular task. The PW system fails because a customer "knows someone in one of the divisions who can get the job done fast, without all that paper work" or when the PWO goes directly to a division because "the Commanding Officer wants it ASAP". Based on information gathered during the NPS case study, these shortcuts result in cost overruns, supply shortages and the overall inability of the PWD to function correctly.

This section was designed to give the PW novice the requisite knowledge base to glean the desired information from the study. Briefly discussed were the PWD mission, organization, and functions. Additionally, the PW environment and some of the typical problems encountered were discussed. The section was by no means a comprehensive description of the PW arena, but a brief introduction.

H. ORGANIZATION

Chapter II presents the PWD LAN objectives and a methodology used to achieve these objectives. Topics include; preliminary information gathering, introductions, interviews, questionnaires, walkthroughs, and analysis considerations.

The actual physical design is investigated in Chapter III. Questions concerning the specific network environment, such as, interfacing requirements, software requirements, and physical blueprint are tendered. The chapter continues with considerations, restrictions and recommendations with regard to the cable plant. Decision trees for optimal file server and workstation configuration are presented. The network operating system along with some of its basic characteristics are examined.

In Chapter IV a review of the PWMA Requirements Evaluation document (deliverable) is conducted.

Finally, Chapter V presents conclusions derived from this study. Recommendations are presented for consideration by both the analyst and the implementing organization. To stimulate interest for academic purposes, advice concerning areas of further research is given.

II. SYSTEM ANALYSIS

> There are two fundamental issues that data gathering plans must consider: the effects of measurement on the people and the effects of the people on the measurements. [Ref. 7:p. 303]

A. INTRODUCTION

The first phase of the WESTDIV Local Area Network Assistance Visit is the analysis phase. For the purposes of this study, "analysis is the separation of an information system into its component parts for the purpose of identifying and evaluating problems, opportunities, constraints, and needs." [Ref. 8:p. 179] During the analysis phase all aspects of the present PWMA system will be investigated along with any future system expansions or alterations.

This chapter presents the analysis objectives and a step-wise plan for achieving these objectives. The analysis process described, with the exception of the preliminary information, should be completed in week number one of the site visit. The intelligence collected will be applied in week two as the basis for the LAN design.

B. ANALYSIS OBJECTIVES

"Data gathered without any clear objective is unlikely to be useful. Since any complex process involves a host of parameters, the chance of accidentally gathering the right information is

remote." [Ref. 7:p. 302] To ensure the proper information is gathered during the analysis period, an objective tree is presented (see Figure 2.1). When analyzing a costumer's needs, especially working with a field as dynamic as the automation industry, it is important to consider their future requirements in addition to their present uses. Dividing both of these areas into internal and external components makes then more manageable. Even with this division it is often difficult to extract the needed information. Questions such as: who to talk to, when to talk to them, and what to ask, are difficult to answer. Often it

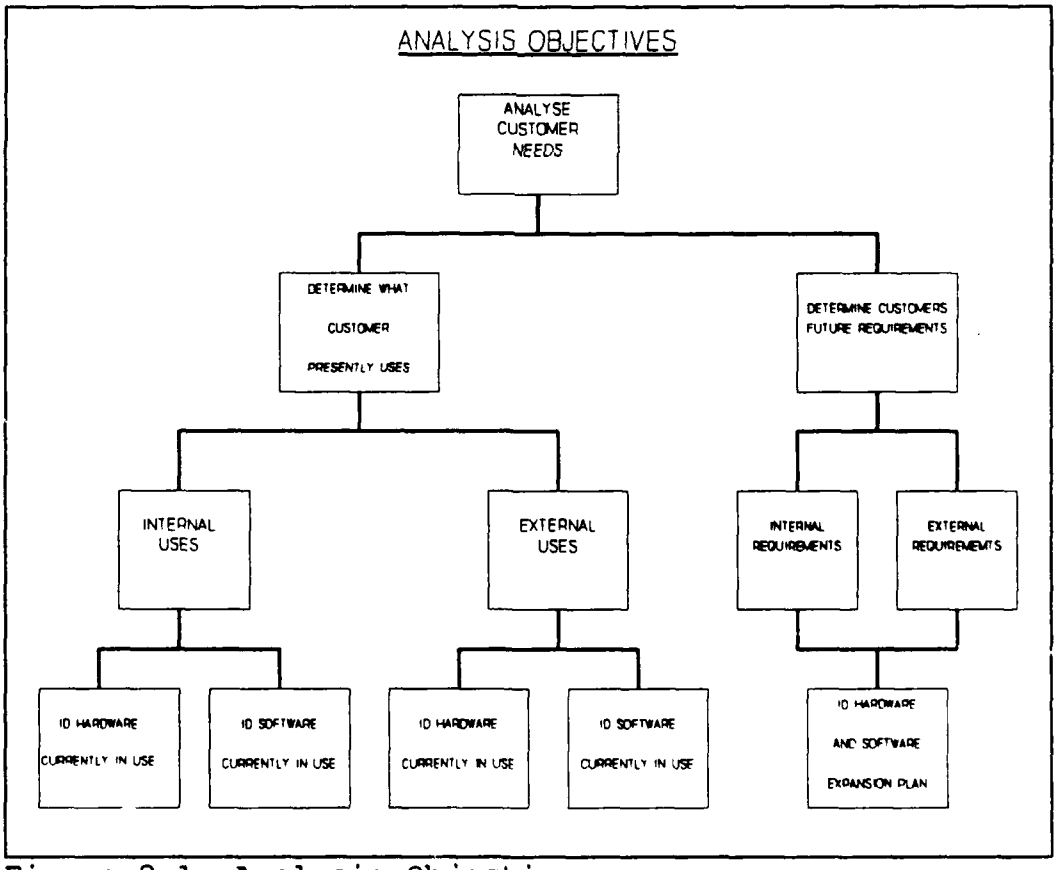


Figure 2.1 Analysis Objectives

is more important to know how to ask and when to listen. The following section will begin a description of the analysis plan designed to answer the questions and capture these elusive objectives.

C. ANALYSIS PLAN

At the completion of the first week, the analysis period, all elements of the objective tree should be identified. The information required to identify all the branches in the objective tree will be gleaned by carefully completing each phase of the analysis plan described in the remainder of this chapter. The analyst should continually refer back to the objective tree to ensure the necessary data are being extracted during each phase.

The analysis plan consists of six different phases: Preliminary Information and Preparation, PWO Interview, Department Brief, Division Interviews, External Relationship Meetings, and Division Walkthroughs. All six phases and their associated documents were utilized during the NPS case study. Any discrepancies in the techniques or content of the phases were noted and corrections made prior to this writing.

As indicated by the Analysis Plan flow chart (see Figure 2.2) phase 1, Preliminary Information and Preparation, occurs prior to the site visit. Additionally, the sequence of the

phases is important with the exception of the last three which can be completed simultaneously. Finally, it can be seen from Figure 2.2 the Analysis plan is iterative and may require several passes to ensure all of the objectives are ascertained.

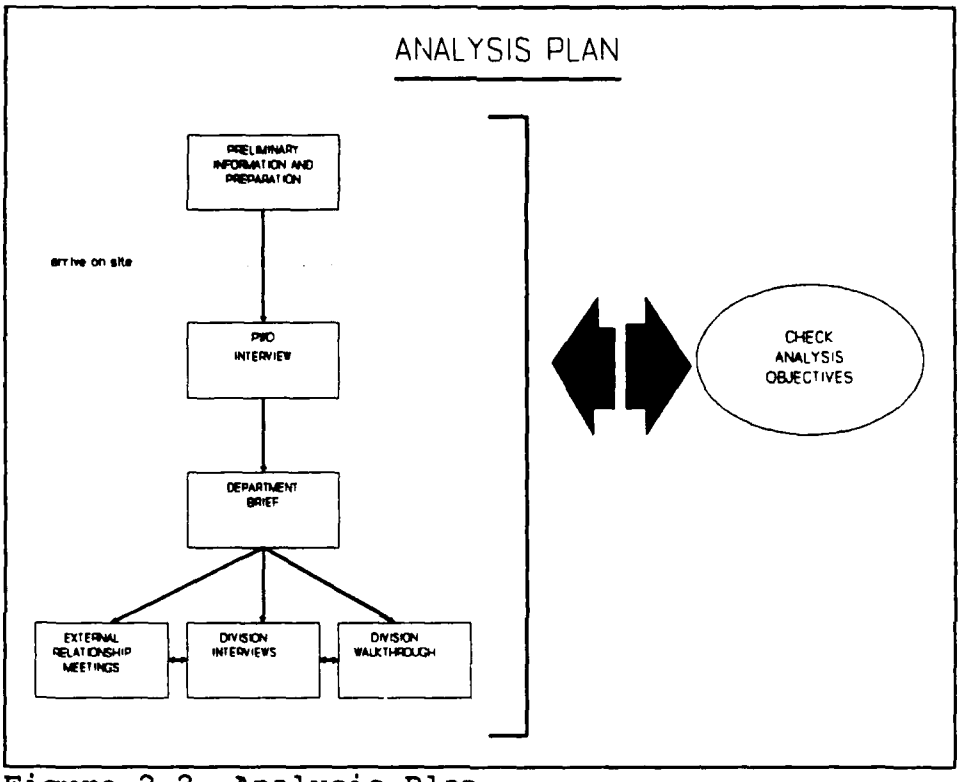


Figure 2.2 Analysis Plan

In the remainder of this chapter, one section will be devoted to each of the six phases. Once again, the reader is reminded that the plan was designed and should be utilized with the idea of achieving the analysis objectives (Figure 2.1).

D. PRELIMINARY INFORMATION AND PREPARATION

The Analysis Plan begins approximately six weeks prior to the site visit. At this time, in response to an Engineering Service Request from the PWD in question, the analyst should forward to the PWD a brief introduction letter proposing the impending visit and its objectives.

1. Introduction Letter

A sample of this letter can be found in Appendix A. Although this is just a sample there are a four points that should be strictly adhered to. First, the letter routing should be from Commanding Officer WESTDIV, establishing credibility and interest on WESTDIV's part, to the PWO. No action will be requested of the PWO personally; he will be asked to delegate to a subordinate. This will ensure compliance and, more importantly, begin to foster the command support required. Command support is essential for effective analysis and design and will be discussed further in the following sections. In addition, the PWO may have some personal feelings regarding past, present, or future automation and this will allow him to be fully advised of the impending visit and the necessary preparations.

Second, the letter should request the enclosure (see Appendix B) be forwarded to the PWD Automated Data Processing representative (ADP Rep) for action. The ADP Rep, who also understands the idiosyncracies of the specific automation

environment, has access to a majority of the information required to complete Appendix B. Dividing this responsibility among other personnel or neglecting to include the ADP Rep, could result in loss of control, severed communications, and erroneous data.

Third, it is important, from the beginning, that the activity in question does not perceive the visit as threatening. Although one Engineering Field Division (EFD) function is to perform Facilities Evaluation and Assistance (FEAT) visits, it is crucial the PWD understand this is not an inspection. "Unless it is continually emphasized that the process measures will not be used to evaluate their performance, people will often go to great lengths to make the numbers 'look good'". [Ref. 7:p. 303] If this misconception is pervasive some of the most critical data will be concealed. Every effort must be made to ensure the personnel understand the EFD is present to lend assistance not to inspect. This concept is important throughout the entire process and begins with a carefully worded, nondirective, introduction letter. The dates for the site visit should be proposed not directed and the names of the review team should be provided to give it a personal touch.

Finally, as a whole, the letter should be brief. At this stage of the process, there is little interest in or time allocated for the LAN visit. The idea is merely to get the ball rolling in the right direction.

2. Information Systems Review and Preparation Sheet

Enclosed in the Introduction letter will be the Information System Review and Preparation Sheet (Prep Sheet) (Appendix B). The Prep Sheet has three sections: the Preparation Schedule, the Preliminary Information, and the Preparation. The following sections will give a brief explanation of the contents of the Prep Sheet. It will be helpful to refer to Appendix B while reading the following sections.

a. Preparation Schedule

The Preparation Schedule provides a time line, with four milestones, starting from receipt of the enclosure. One week after receipt the ADP Rep is asked to call the EFD to solidify the proposed dates, ask any preliminary questions, and to provide the EFD with a point of contact. Three weeks prior to the visit it is incumbent upon the EFD to contact the ADP Rep. This milestone is to ensure the data gathering process has begun, hopefully avoiding a last minute rush job. It is also an opportunity for the ADP Rep to ask more in-depth questions. Additionally, in preparation for the initial interview with the PWO, the analyst should take this opportunity to ask the ADP Rep about the PWO's knowledge of and attitude towards automated data

processing. Finally, two weeks prior to the arrival of the review team the ADP Rep is instructed to mail the Prep Sheet to the EFD.

b. Preliminary Information

The Preliminary Information is the nucleus of the Prep Sheet. This section is divided into four parts: Base Information, Base ADP Information, Existing PW ADP Systems, and Proposed PW ADP Systems. It is essential the data provided is current, accurate, and timely.

(1) Base Information. The Base Information includes Base Maps (indicating building locations), Individual drawings (to scale), and Base Cabling Diagrams. These documents can be obtained from the PW Engineering Division and will most likely be in blueprint format. All will be verified in the Analysis phase and utilized during the Design phase.

(2) Base ADP Information. The Base ADP Information is designed to gather data to ensure any system installed in PW is compatible with any other existing or planned systems aboard the base. At the time of this study the number of bases having overall ADP managers and base wide plans are few. If, however, this information is available it is critical that integration efforts be made. Knowledge concerning any existing external systems, in the absents of a base wide plan, will be most helpful.

(3) Existing PW ADP Systems. The Existing PW ADP Systems information should be a listing of all of the ADP equipment utilized by the PWD. The System Equipment should be numbered, one through the total number of systems, and the necessary details provided. Additionally, any limitations or problems, such as, memory shortages, insufficient disk storage, or slow response times should be noted. The System Utilization should be matched with the system number from the System Equipment segment. In this segment the Primary Utilization and Frequency of System Use are self explanatory. The Communication Requirements refers to not only automated communications but also manual communications. This will establish the beginning of any interface requirements for the impending network. The Annual Cost per System includes training and maintenance for both software and hardware. The consumable costs, such as, paper, disks, and printer ribbons must also be included.

(4) Proposed PW ADP Systems. The Proposed PW ADP Systems applies to any systems not presently on-hand and any upgrades or enhancements to existing systems. The status of these systems and the date of the next major event in its cycle are required. The remainder of the segments in the Proposed PW ADP Systems section are similar to the Existing Systems portion except most of the data is projected.

c. Site Preparation

To allow the evaluation team to effectively function for a period of two weeks it is paramount to make a conference available. It will serve as the location for interviews and meetings. Additionally, the conference room will function as a central work position where team members can be reached or can contact external units. It would be most helpful if a telephone were available in the conference room. The room must accommodate at least eight people. A conference style table, large enough to spread blueprints on, is also required.

Finally, the ADP Rep is requested to schedule a series of meetings. On day one of the visit, two fifteen minute interviews, the first with the PWO and the second with the department division heads, should be arranged. Additionally, scheduled sometime in the first three days, at the division head's convenience, should be sixty minute meetings with each division head.

The three sections of the Prep Sheet: Preparation Schedule, Preliminary Information, and Site Preparation, completed in a timely and accurate fashion will provide the analyst with the necessary information to begin a comprehensive evaluation of the technical feasibility of network analysis and design.

E. PUBLIC WORKS OFFICER INTERVIEW

"The most important element of an information system is people. And more than anything else, people want to be in on things." [Ref. 8:p. 745] Conducting interviews is the best known method for involving people and a premier fact-finding technique. Despite this, analysts as a whole are poor interviewers, lacking the required interpersonal skills to communicate effectively. [Ref. 8:p. 745]

The use of interviews and interviewing techniques are required to conduct a successful evaluation. It is not the purpose of this study to provide a comprehensive outline of successful interviewing procedures, however, some basic techniques along with some techniques specifically applicable to the PW arena are provided. Although each interview has its own format and objectives, the following techniques can always be effectively applied.

- SCHEDULE INTERVIEWS - never drop in unannounced, this is usually unproductive
- LIMIT INTERVIEW - normally a half hour, maximum one hour, the higher the management level the shorter the interview
- BE PREPARED - learn about the individual's personal motivations and biases, be knowledgeable in the interview area
- ONE INTERVIEWER ONE OBSERVER - it is difficult to interview and observe at the same time, divide the duties to increase overall effectiveness

- COMMUNICATE ON INTERVIEWEE'S LEVEL - speak in their language, don't get too technical
- LISTEN AND OBSERVE CAREFULLY - watch for both verbal and nonverbal communication

If conducted correctly the interview will generate support, establish credibility, and allow the analyst to get a feel for the current system and any problems. A successful interview with the PWO is the first and most important step.

Assuming that the ADP Rep has done as instructed in the Prep Sheet, the PWO interview should have already been scheduled to take place in the PWO's office with the APWO present if desired. The time allotted should be fifteen minutes. Do not schedule for more than fifteen minutes except at the request of the PWO. Fifteen minutes is ample time to accomplish the interview objective. It is strongly advised to schedule the interview prior to arrival on site to avoid confusion.

To be prepared for the interview it is especially important for the analysts to have learned as much as possible about the PWO's strengths, fears, biases, and motivations. Of particular significance is the PWO's knowledge of and attitude towards automated information processing. The necessary intelligence can be obtained from the ADP Rep, the APWO or both.

The actual interview with the PWO will be unstructured. In an unstructured interview, "the interviewer conducts the

interview with only a general goal or subject in mind and few, if any, specific questions. The interviewer counts on the interviewee to provide a framework and direct the conversation." [Ref. 8:p. 746] The interview will be organized into three phases: the opening, body, and conclusion. "The opening is intended to influence or motivate the interviewee to participate and communicate by establishing an ideal environment. When establishing an environment of mutual trust and respect, you should identify the purpose and length of the interview and explain how the gathered data will be used." [Ref. 8:p. 749] During the opening the analysts will briefly explain to the PWO they will provide assistance in any way possible, but the primary goal is the analysis and design of a LAN for future implementation. As discussed earlier it is important the analysts communicate on the PWO's level. An in depth discussion concerning the intricacies of networking, analysis, or design procedures should be delivered by direct request only. The opening should be short and poignant, lasting approximately five minutes.

The body of the interview is the longest portion of the interview lasting almost 10 minutes. Normally, during the body the interviewer would obtain responses to a list of prearranged questions and control the interview carefully to keep it on track. However, in an unstructured interview the object is to

get a feel for the existing PW environment aboard the base. To accomplish this the analyst should ask the PWO what problems exist in his department and what he is expecting from the review team. Allow the PWO to control the meeting. The interview may begin to meander; irrelevant aspects may surface; in this situation it is permissible. Pay close attention and take notes on both the verbal and nonverbal communication. Many hidden problem areas, which are difficult to isolate in a controlled exchange, can be identified during this free flow of information.

During the conclusion, which should last no more than sixty seconds, the analyst should acknowledge any unanswered questions, express their appreciation, reemphasize their role as assistants vice inspectors, and inform the PWO they will conduct an out-brief prior to departure. Most importantly, the PWO should be asked to introduce and express his support of the evaluation team at the Department Brief. This is critical. "Any organizational change which does not have the support and commitment of top level management has a slim chance of success." [Ref. 9:pp. 7-14] The introduction provides two essential elements: command support and credibility. In the absents of either the division heads will have a tendency not to place the proper emphasis on the project and without their help the necessary materials and data can not be assembled.

F. DEPARTMENT BRIEF

The Department Brief will be the analysts first exposure to the personnel of the PWD and vice versa. The success of the site visit, at least partially, will rest on this initial impression. Although not purely an interview, all of the techniques discussed in the previous section should be adhered to and will not be reiterated in this section accept where emphasis is required. The brief, held in the conference room, should be broken into four parts: the introduction, the opening, the body, and the conclusion. In the introduction the PWO should present the evaluation team, express his support, and request compliance from his personnel.

The opening, as in the PWO interview, provides initial details on how and why information will be gathered. More importantly, it establishes a rapport with the attendants. Once again, the first message to convey is that the team is present to assist and not inspect. As the analyst proceeds down the chain of command this central idea becomes more and more difficult to impart. Finally, it is helpful provide a quick promotion of the benefits of a LAN. Included should be an overview of LAN functions and how it will effect the individual division heads and their personnel. The opening should consume no more than five minutes.

The body of the brief is similar to the body of the PWO interview. The idea is to open the floor for any questions, comments, or complaints. During this exchange of information it is the team member assuming the role of observer who has the critical job. Observing and recording the interaction between the division heads often reveals some extremely useful intelligence. Where people sit, who they talk with, and the manner in which they address each other, all serve to paint a more concise picture. Information blockages, informal communications, and other problem areas can also be identified by a conscientious observer. Such knowledge makes the analysts more prepared for the Division Interviews by providing the necessary information to tailor the interview to the interviewee. The body should last approximately 10 minutes.

As with the conclusion for the PWO interview the Department Brief conclusion should answer any lingering questions and express gratitude for the cooperation. Two additional items need to be covered: preparation for the Division Interviews, and the LAN class. In preparation for the division interview the Information Exchange Sheet (IES) (Appendix C) should be distributed. The IES is to be filled out, the required reports and documents attached and presented by the division heads during their interview. Placing an X where there is any type of information exchanged between units creates a data audit trail.

Comparing and contrasting all of the IESs serves to further illuminate the actual information flow and to identify potential network interfaces. Additionally, in preparation, the division heads should be requested to bring to the interview any of their technical or ADP personnel.

A short class on the basics of Local Area Networking should be offered to any personnel in the department. "Education and training of users is an integral part of the system development process." [Ref. 10:p. 282] Understanding through education is the best way to gain support and acceptance. A major objective of the training function is to make users familiar and comfortable with the new system. "The process should lead naturally to an acceptance of the system, in which the users, its true owners, assume responsibility for its successful application and routine operation." [Ref. 10:p. 283] Although it will be sometime before the PW personnel are ready and able to take charge of the forthcoming network, a short instructional period on the rudiments of LAN's is an essential first step in the right direction.

G. DIVISION INTERVIEWS

The objective of the division interviews is to identify three present and future areas in each division: resources, functions, and requirements. Before reviewing the Interview

Procedure to achieve these objectives there are a few Preliminary Preparations.

1. **Interview Preparation**

First, assuming the Prep Sheet instructions were followed, the interviews, to be held in the conference room, should already have been scheduled prior to arrival. It is important the interviews take place in the conference room and not in the division head offices. The idea here is to get the division heads away from their offices to eliminate any distractions and to allow them to speak more freely. Second, as mentioned in the Department Brief section, the division heads should be encouraged to bring any of their technical or computer people. Third, much of the information gathered will be redundant or a clarification, however, this is necessary to validate the data. Finally, to be prepared for the interview, the review team should plan, based on the observations during the Department Brief, how they intend to tailor the interview to the interviewee. Establishing the appropriate level of communication will greatly enhance the flow of information.

2. **Interview Procedure**

Unlike the previously discussed interviews the division head interview should have less structure. The interview should be scheduled for one hour with the analyst carefully controlling the session to ensure the necessary information is gleaned. As

an aide to assist the analyst in gathering the information to achieve the stated objectives the Division Analysis Sheet (DAS) should be utilized (Appendix D). The following paragraphs will give a brief description of the DAS and how to gather the information to complete it.

a. Staff Size

After the Division, POC, and Phone entries have been completed, data concerning the division personnel must be collected. The entry for Present Staff Size should not be the number of personnel on the division Table of Order (TO), but the actual number of people the division is presently operating with. It is rare to find a division that is fully staffed to its TO. Next, because the analysis is being conducted for future implementation, any Anticipated Staff Change must be considered. Whether this is a staff increase or a staff decrease, it will affect the network area. Finally, the Present Staff Size and the Anticipated Staff Growth are combined to achieve the Total. Further analysis of the particular division should be based of the Total staff size.

b. Function

The Present Function of the division must be identified. The function will dictate the type and amount of ADP support required. The Shops division, for example, will not demand the same variety of equipment the Engineering division

will. Any changes in the Future Function of the division and when they will occur need to be considered. Weighing both Present and Future Functions will provide the desired level of system flexibility and adaptability.

c. Users and Applications

The number of ADP equipment users and the primary applications utilized will begin to provide the analyst with an idea of the types of hardware, software, and communications gear required to make the transition to a microcomputer based LAN. Additionally, the interviewer will gain a feel for the level of ADP sophistication in the division. Large numbers of users and complicated applications indicate an advanced degree of computer knowledge and lends more credibility to user requests and suggestions. Divisions displaying these characteristics are more likely to have a good idea of what they expect from an ADP system and, as a result, are an excellent intelligence source for the analyst. Correctly completing the DAS for these divisions will be relatively effortless. If on the other hand, the division is not computer oriented then it will be difficult for the analyst to extract the essential information. Requests made by these divisions must be somewhat suspect and closely scrutinized by the analyst.

The following three sections of the DAS are the Hardware, Software, and Communications sections. Before

beginning a discussion on the particulars of these sections, it is important that the analyst understand the premise behind these data gathering sections of the process. Here it is the analysts job to not only ascertain the amount and type of equipment the user has on-hand, but what the user thinks he needs in the future. In other words the Required/Desired column of the DAS is a wish list for the division heads. This must be weighted against the credibility of the interviewee and the analysts personal knowledge of the functions and requirements of each division. Albeit, one of the basic criteria advocated by WESTDIV is that systems be designed to allow for flexibility and future growth. Thus, given that design occurs relatively early in the system life cycle and the implementation phase may not occur for quite some time, it is recommended the analyst focus on system expendability using state of the art equipment to ensure the system is not antiquated, under powered, or inadequate upon completion.

d. Hardware

The Hardware section of the DAS is divided into two sections: Existing Quantity and Type, and Required/Desired. In completing the information on existing equipment, all equipment, including personally owned, should be accounted for. Personal systems utilized in the work place will have to be identified and replaced to allow integration with the network.

This change will most likely be resisted and may require a policy change promulgated by the PWO.

To describe the type of equipment the entry should include the brand name and model number. In the case of central processing units (CPU) the amount of random access memory (RAM), and the clock speed should also be indicated.

As discussed previously the Required/Desired entries should include the equipment necessary to ideally accomplish all of the user requirements. It is preferable to design a system too large than too small.

e. Software

The Software section is divided as the Hardware section is, however, in most cases the large number of different software packages being utilized and the attitude towards particular packages complicates the matter some what. Managers and their subordinates are becoming more and more computer literate. They are performing a myriad functions that are independent of their business specialties. The computing industry has responded by developing microcomputer software to do everything from write to manage. Unfortunately there is no standard. This lack of a standard has resulted in personal opinions as to which particular package is better than another. Familiarity with most packages leads to the illusion of product superiority and a resulting inflexibility. Based on the NPS case

study and personal observations in various other environments, generally, once people have taken the time to learn a package they actively resist the idea of switching.

However, with the advent of the LAN it has become necessary to standardize and this is where the problem begins. As a result, in most cases it will be necessary for the PWO to select a standard for the various types of applications software.

f. Communication

The final section of the DAS is Communication. Communications can be defined by "the transmission of information and understanding through the use of common symbols." [Ref. 11:p. 631] The identification of communication paths is essential to allow for the proper system integration. The analyst should identify all of the transactions currently processed, all prospective transactions, and any problems or opportunities that exist relative to these transactions. "The analyst should not restrict the study to those transactions processed on the computer. Manually processed transactions, including both verbal and written, are equally important!" [Ref. 8:pp. 183-184] It is most important, before proceeding any farther, the analysts ensure the users understand these fundamental concepts.

The analyst and the interviewee should review the Information Exchange Sheet along with any of the attached formal

or informal reports. In reviewing this information an emphasis should be placed on how the information is gathered, processed, and utilized as well as any existing problems. Following an assessment of these documents, completion of the Communication section should begin.

For each individual communication an application section should be completed with the following. First, the Interface Organization must be identified. In some cases the transaction will occur internally. This is legitimate and should be recorded as accurately as possible. Second, if the functional connection exists the Transaction Name, Frequency and number of concurrent sessions should be indicated. If the functional connection does not exist then the entries should be completed to best describe the anticipated or desired transaction. Finally, indicate any problems or peculiarities with the application.

To complete the Communication section the existing and required modes of communication must be delineated by application number. Note, in completing this portion of the DAS the analyst may find the users provide little input. This is primarily due to a lack of understanding in the relatively new field of microcomputer communications. If confronted with this situation, it would behove the analyst to lower the discussion level allowing the participants to communicate their requirements

more effectively. Any holes in the information can be filled later in the analysis phase.

A majority of the existing type of communication will be either Honeywell or Manual. The transition of most of these applications to the network will be accomplished by the BEST software modules. To describe any other type of existing interface equipment the entry should include the brand name and model number. In the case of modems the transmission speed should also be indicated.

Finally, the Required/Desired entries need to be completed. As indicated earlier the analyst may receive little help from the user, particularly on this portion, and may chose to move quickly through this part and complete it after the meeting. Many of the interfaces will inherently be satisfied by network installation, but should still be identified as requirements.

Upon completion of the Division Interview the survey team should have identified a majority of the present and future, resources, functions, and requirements. At least ninety percent of the DAS should be filled out and comments inserted where questions or variances exist. Prior to concluding the meeting a time and date for a division walkthrough should be set. Unless the division has some outlying areas or unique

characteristics, one hour will be enough time to conduct this exercise.

It is advised that the analysts confer immediately following the meeting. While the information and characteristics of the division players and status are fresh, a quick discussion on current status, impending problems, idiosyncracies, and suggested options should be discussed and recorded in the Final Comments section of the DAS.

H. DIVISION WALKTHROUGH

Thus far in the analysis phase a large amount of data from varying sources has been gathered. Due to organizational complexities and the advanced technology dealt with during network analysis, conceptual, logical, and physical errors in the data are bound to exist. The only way to eliminate these errors is to continue to work closely with the user and his staff, testing and checking for accuracy in their representation of division operations. The best major tool in such an effort is the walkthrough. [Ref. 12:p. 110]

"The walkthrough is a peer group review of systems development documentation. Walkthroughs may be used to verify virtually any type of detailed documentation." [Ref. 8:p. 766] Standard procedure for a walkthrough, according to Ed Yourdon's Structured Walkthroughs [Ref. 13], cited in the bibliography,

would involve conducting a meeting to review documentation. However, for the purposes of this study the walkthrough will involve an actual physical survey of the implementation area. Physical inspection of the installation grounds and office spaces will allow the survey team and the users to detect and correct errors, as well as, anticipate any problems. There are several preparation steps to be completed before the walkthrough can begin.

1. **Walkthrough Preparation**

Preparation for the walkthrough involves the consolidation of information gathered and familiarization with the walkthrough site. To consolidate the information the analysts should first compare and contrast the Prep Sheet, provided by the ADP Rep, the Information Exchange Sheet, provided by the division head, and the DAS, completed during the Division Interview. Attention should be focused on missing information, conflicts, and apparent limitations. At this point, a list of questions to be asked during the walkthrough should be assembled.

To assist the survey team in organizing this list the Walkthrough Action List (WAL) [Ref. 14:p. 346 fig. 19.4] (Appendix E) is provided. Any questions, discrepancies, or absence of intelligence should be documented by completing the Issue Raised section of the WAL. Fill the Reference entry with the source of the issue in question. The references are not

limited to the analysis documents. An observed question or a verbal discrepancy gleaned from one of the interviews are legitimate references. The action portion of the WAL is to be completed during the actual walkthrough.

The next preparation step is for the analysts to familiarize themselves with the walkthrough area. A through understanding of the layout of the areas to be examined is essential to ensure the physical feasibility of network installation. Review of the facility and division office blueprints will provide this indispensable knowledge. If the requisite blueprints have not been provided this is the time to retrieve them. Incomplete knowledge at this stage, due to missing information of the inspection area, will limit the productivity of the walkthrough and greatly increase rework during the design phase.

2. **Walkthrough Procedure**

The procedure used during a walkthrough has three basic principles. First, a division of labor between the two analysts. One should be assigned as the walkthrough coordinator. The coordinator ensures the walkthrough is conducted properly. Several important functions performed by the coordinator are: ensuring all questions on the WAL are covered, keeping the walkthrough on relevant topics, soliciting input from all members of the walkthrough team, and mediating any disputes or problems

that arise. The coordinator depends on the recorder for assistance.

The second analyst is assigned as the walkthrough recorder. The recorder has a number of responsibilities: ensuring the questions answered are recorded in the action portion of the WAL, assisting the coordinator by making sure all of the issues on the WAL are examined, recording any other pertinent observations, and by providing the coordinator with any other assistance deemed necessary.

The second principle is the inclusion of the users as part of the walkthrough team. "Experience indicates that users particularly enjoy walkthroughs because such meetings encourage a sense of personal importance in the project." [Ref. 8:p. 767] In this case the users are the actual personnel working in the various divisions. However, it is recommended, due to the possibility of biased information and time constraints, the walkthrough team only include users down to the general foreman level. All members of the team should be treated as equals and be encouraged to provide input. This type of peer group analysis, the walkthrough, will tend to identify errors that might go unnoticed by the analysts and top level management.

3. Walkthrough Objectives

As mentioned earlier in this section, one of two primary objectives of the walkthrough is to validate and complete

the information gathered up to this point in the analysis phase. Physical inspection will not only allow the team to detect any major changes and correct errors, but will give the analysts their first opportunity to investigate some of the aspects effecting the physical design of the network area, the second primary objective.

Identification and clarification of the physical layout and its components will give the survey team an idea of the design alternatives to be investigated. Although additional inspections will most likely need to occur during the design phase, to ensure accuracy, the following areas should be investigated during the walkthrough: office and facility layout, deviations from existing blueprints, location and type of existing equipment, cable run requirements, physical obstructions, electrical power availability and requirements, and existing and required conduit and cable tray. These items of interest are to be explored with the intent of transposing all of the pertinent data on to the appropriate blueprints during the design phase. This is why in preparation for the walkthrough a thorough understanding of the facility and office layouts is imperative.

Effective and efficient completion of the walkthrough process will result in a more accurate view of the situation. More importantly, the completion and verification of the analysis objectives at this time will reduce rework in the design phase.

III. SYSTEM DESIGN

A. INTRODUCTION

> Designers must work hard to learn as much as possible about the users of the system and the work they do with it. They must assume that their design ideas, even given this background information, will be wrong, and plan for repeated redesign. [Ref. 15:p. 5]

Chapter II provided specific analysis objectives and a recommended step-wise methodology for achieving these objectives.

Before beginning the actual design phase it is important that all of the data gathered during the analysis phase has been consolidated, compared, and contrasted. A final consensus of the present and future requirements of the installation must be formulated. All present and future workstations, and all existing and required cable runs should be transposed onto a master blueprint. This gives the designers a macroscopic view of the system and, as such, is a most useful document for the design phase.

Design is the hardest phase to communicate to the reader. It is different from the analysis phase, where the system already exists and the procedures for gathering the needed information can be well defined. The idea of a correct or best design for a given system is an elusive concept. What is correct for one system, may not be correct for another. Dynamic factors such as personnel, physical location, and organizational structure

further cloud the issue. "Design requires considerable creativity to make the necessary system-specific changes and additions and come up with a new system that is acceptable to users and easy to implement." [Ref. 14:p. 194]

As a result, it is difficult to present a design methodology which will take into account all of the variables and produce the appropriate solution for every system. The designer is called upon to search for the best solution utilizing any special knowledge gleaned from his past experience and the analysis phase.

Despite the elusive nature of the design phase it is necessary to have some semi-structured process to guide the designer. This is the objective of Chapter III. Using information learned during a case study of the Naval Postgraduate School (NPS) PWD and the available academic resources, design objectives and a methodology to achieve these objectives are presented.

The hardware and software components intrinsically involved in the design of a microcomputer based system are extremely complex. The object of this chapter is not to provide an in-depth explanation of all the components, their characteristics and their interrelationships, but to give a simplified way to identify the needed components and their role in the system as a whole. However, where deemed necessary for clarification

purposes, brief explanations of the technology will be given. In order to provide some continuity in this arena standards are enforced.

B. DESIGN STANDARDS

Both the government and private sector recognize the need for a common set of data communications protocols. As a result, on 21 January, 1988 the Secretary of Commerce, tasked by Public Law 89-306 (Brooks Act) with the responsibility for improving the utilization and management of computers in the Federal Government, adopted Federal Information Processing Standard (FIPS) 146. This FIPS specifies the use of the Government Open Systems Interconnection Profile (GOSIP) for the acquisition of networks and services. GOSIP defines a common set of data communications protocols which enable systems developed by different vendors to interoperate and enable the users if different applications on these systems to exchange information. It is highly recommended, prior to proceeding with any design aspects, the designers acquire and become familiar with these publications.

C. DESIGN OBJECTIVES

A realistic design should always begin with a set of clearly defined objectives. It is true that once the LAN is installed objectives beyond those initially envisioned will become

apparent. "However, there are some things that must be accomplished with the LAN, and those things should be the basis of a list of design objectives." [Ref. 16:p. 70]

Based on the NPS case study and various academic resources, a list of design objectives for a PWD LAN is provided in Table I.

TABLE I

DESIGN OBJECTIVES

1.	Design a system the users will find useful, easy to learn, and easy to use
2.	Design a system that supports the PW mission
3.	Design a system that supports the BEST software modules and the user desired applications programs
4.	Design a system that provides the proper functionality for the least cost
5.	Prepare detailed specifications for the cable plant, hardware, and software system components that best meet the PWD needs

A user friendly system as an objective is most important. "In the rush of enthusiasm that accompanies the installation of a LAN, those most deeply involved with the project (the designers) may forget that the objective is not the installation of the

network, per se. Rather, the network is installed to provide useful services for its users." [Ref. 16:p. 183]

As stated in the introductory chapter, the sole purpose of a PWD is to provide quality services and products in a cost efficient and responsive fashion to their host commands. Any system that does not support this mission is an ineffective utilization of available resources.

The BEST software modules are presently being converted to run on a LAN. The network version of the BEST subsystem will be compatible with Microsoft version 3.0 (or higher) disk operating system based networks. The network should also support the applications software requested by the users. Based on observations made during the NPS case study, any attempt by the designer to force the use of a particular application package, based solely on compatibility with the network hardware or operating system, will significantly reduce the perceived user friendliness of the system.

Given the system accomplishes the previously stated objectives, the designers must concern themselves with the cost of the system. The amount of funds available for the purchase and implementation of a LAN will differ from one installation to the next. However, it can be assumed in most circumstances, that a cost effective solution is most desirable.

The final objective of the designers is to provide a detailed list of the equipment required to complete the network. This Requirements Evaluation should include the cable plant, hardware, and software components of the LAN. Specifications and prices for all items should also be included. Further details concerning the Requirements Evaluation are presented in Chapter IV.

Accomplishing these basic objectives should insure that the system will become an integral and useful tool for the Public Works Department. The following section will present a methodology for accomplishing the design objectives.

D. DESIGN METHODOLOGY

Upon completing the design phase, all of the design objectives should be accomplished. The information required to complete the objectives will be gleaned by carefully completing each step of the design methodology described in the remaindered of this chapter. The analyst should continually refer back to the objectives to ensure the necessary data are being extracted during each step.

The design methodology consists of six different steps: Define Software Requirements, Define Hardware Requirements, Define Cable Plant Requirements, Adjust for New Information, Evaluate Alternatives, and Select/Report (see Figure 3.1). As

indicated in the figure steps four and five, Adjust for New Information and Evaluate Alternatives, are being performed continually throughout the primary steps, one through three. In the remainder of this chapter, one section will be devoted to each of the three primary steps, another section for steps four and five, and step six will be outline in Chapter IV. Once again, the reader is reminded that the methodology was created and should be utilized with the idea of achieving the design objectives.

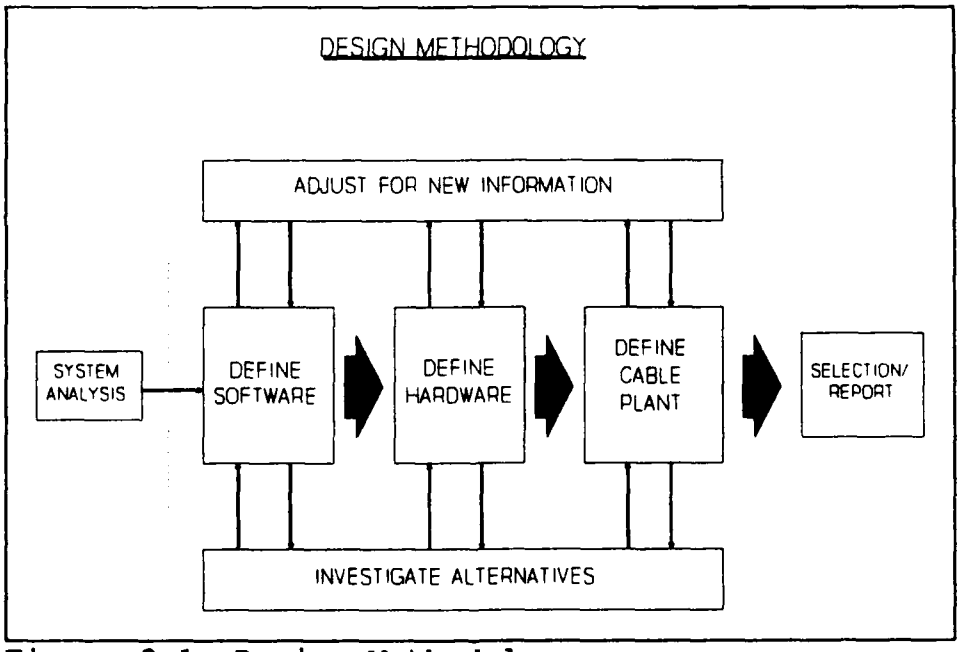


Figure 3.1 Design Methodology

E. DEFINE SOFTWARE REQUIREMENTS

Software requirements can be analyzed from two perspectives: network operating system (NOS) software and the applications software that runs on the network. All LANs have NOS software to facilitate basic network management, file transfer, resource sharing, and connectivity functions. Additional services that may be available, depending on the vendor, are electronic mail, remote access, data security, and print spooling. For the purposes of this study it is not important which NOS is utilized, but that it successfully interfaces with the applications software to provide the desired functionality.

There are two aspects of the applications software which must be defined, the specific applications software selected and the load placed on the network by these applications. The types of applications required by the PWD should have already been gathered during the analysis phase. The required/desired column in the software section of the Division Analysis Sheet (DAS) (Appendix D) should contain the pertinent information. Initially, it would appear that the selection the appropriate brand of application software would be rather simplistic. However, as mentioned earlier in the analysis chapter the lack of standards and the influence of personal opinion on the subject complicates the issue.

When operating in a LAN environment it is best to select one package for each type of application. For example, one package such as Word Perfect for word processing. To have several different brands of word processing software residing on the network simultaneously is extremely inefficient. The additional software costs additional dollars and creates unnecessary traffic on the network which reduces response time. Additionally, it becomes exponentially more difficult to manage a LAN as software packages are added. Thus, the difficulty comes in deciding which brand to select. Due to the political ramifications, the designers should avoid making this decision for the individual PWDs, but insure that the chosen package has a LAN version to allow proper interface with the NOS. Each type of application places a different load on the network.

The network load or traffic is a critical measurement which will be used to calculate the 'LAN Factor', which in turn will determine various hardware requirements. The network load is a measurement of the frequency and amount of information transmitted over the network data paths and is a function of the type and number of user applications. [Ref 8:p. 572]

For the purposes of this study the user applications can be divided into three basic levels: light traffic, moderate traffic, and heavy traffic. [Ref 17:p. MC41-050-402] Each level has a weighting factor, which is multiplied by the number of

applications used in that level. The number of applications required in each level should be determined by cross referencing the hardware and the software sections of the Division Analysis Sheet. The designer must establish the primary application to be used on each of the desired/required microcomputers or workstations. If the workstation utilization is divided between applications then an appropriate proportion of each weighting factor should be calculated.

Light traffic can be defined by relatively small amounts of data sent sporadically. Examples of such applications are electronic mail (E-mail) and word processing. These applications should receive a low factor of 0 to 15.

Moderate traffic requires the workstations to access the server with a high relative frequency. Examples of such applications are spreadsheets and databases. The rating assigned should be between 15 and 30.

Heavy traffic is incurred during any online operations in which the interactive processes are frequent. Examples of such applications are computer aided design (CAD), management statistics, and network supervision. The BEST software applications, because they are transaction oriented, should also fall into this category. These applications should receive a high factor of 30 to 50.

Table II gives some more specific weightings for various applications. The weighting factor times (X) the number of

Table II

LAN FACTOR CALCULATION

APPLICATION TYPE	WEIGHTING	X	NUMBER OF APPLICATIONS
Very light secretarial, E-mail	3 - 5	X	# = t
Secretarial, Word processing	7 - 13	X	# = t
Management, Spreadsheet	15 - 22	X	# = t
Accounting, Database	25 - 30	X	# = t
Sales, CAD/CAE, Order entry	32 - 35	X	# = t
BEST, Interactive management	36 - 40	X	# = t
		LAN FACTOR =	SUM

[Ref. 18:pp. 79-89]

applications (#) will give a value of t (see Table II). The sum of these t values equals the LAN Factor. The LAN Factor will be used in the hardware section to design the server(s) and their associated storage subsystems.

F. DEFINE HARDWARE REQUIREMENTS

In addition to the software applications and the cable plant, which will be discussed in the next section, there are a

variety hardware components involved in the construction of a LAN. Microcomputers are used as user workstations on the LAN. Through the use of network interface boards and repeaters the workstations are connected to the transmission medium. Most LANs have at least one server station for access by the other stations or nodes on the network. The server must be chosen and configured to handle the anticipated demands of the system.

1. Server Design

The primary purpose of a LAN is to allow users to share files, information, and expensive resources such as laser printers. The server provides the means to deliver these services. "The server station provides a central repository for programs, text, and data that are available to LAN users. The server is either a dedicated device or a PC that handles network service in the background." [Ref. 1:p. C11-010-110]. The server should be located to allow for a central distribution, however, the appropriate amount of physical security, according the environment, should be provided.

The server can be broken into two critical components, in regards to LAN design, the server CPU and the server subsystem. Both the server CPU and the server subsystem should be chosen to accommodate the anticipated network load.

a. *Server CPU Design*

In selecting a server there are two basic criteria. The central processing unit (CPU) type and the processor clock speed. "The CPU is the 'brain' of the computer that controls the interpretation and execution of instructions." [Ref. 16:p. 223] The processor clock speed is the speed at which the instructions are fetched and presented to the CPU for execution. Both the CPU and the clock speed are important factors in decreasing the response time of the network. If chosen incorrectly, all other attempts to increase the speed of the LAN will only have a marginal affect. [Ref. 16:p. 223]

Entering Table III with the LAN Factor calculated in Table II should yield a CPU and clock speed combination to allow for ample processing power and speed for the given network load. Assuming the conservation of funds is an integral part of selecting a server, the designer should select the CPU and clock speed pair with the lowest LAN Factor that accedes the network LAN Factor.

TABLE III

CPU SERVER CONFIGURATION

CPU Type	Clock speed	LAN Factor
80286	8 MHz	Below 75
80286	10 MHz	Below 100
80386	16 MHz	Below 200
80386	20 MHz	Below 300
80386	30 MHz	Below 400
80286: Each Additional Megabyte of RAM		Add 25
80386: Each Additional Megabyte of RAM		Add 50

[Ref. 18:pp. 79-89]

b. Server Subsystem Design

The second essential component of the server is the server subsystem. Through the use of a storage subsystem, the server provides mass storage for other devices and back-up for the network as a whole. For the purposes of this study the subsystem can be defined by the technology, size, and number of the hard disk drives associated with the server.

There are three basic technologies that apply to mass storage devices: Institute of Electrical and Electronic Engineers Standard 506 (IEEE ST-506), Extended Storage Device

Interface (ESDI), and Small Computer System Interface (SCSI, pronounced "scuzzie").

The IEEE ST-506 is the basic storage resource server such as those standard in a typical IBM XT, IBM AT, or compatible PC. The IEEE ST-506 has a bus speed of 5 MHz. The ESDI is an storage device which can support up to two hard drives. The ESDI is a high speed bus with a speed of 10 MHz. The SCSI is a high speed input/output bus that can support up to eight daisy-chained devices, usually hard drives.

Entering Table IV with the number of drives, the type and size, along with the system LAN Factor will yield a server subsystem combination that will allow for sufficient and efficient mass storage and back-up capability.

In order to protect against power fluctuations and outages that could result in the loss of critical data, an essential part of every subsystem should be an uninterruptable power source (UPS). In the event of a electrical spikes, black outs, or brown outs the UPS should, through the use of battery power or power filters, maintain usable power to the server. This type of protection is especially critical in a network environment where a majority of the organizational data is centrally located on the server.

TABLE IV

SERVER STORAGE SUBSYSTEM CONSIDERATIONS

Drive Type	Drive Size	Drive Number	LAN Factor
ST-506	60 Mbyte	1 drive	Below 100
ST-506	60 Mbyte	2 drives	Below 150
ST-506	130 Mbyte	1 drive	Below 150
ST-506	130 Mbyte	2 drives	Below 200
ESDI	150 Mbyte	1 drive	Below 200
ESDI	150 Mbyte	2 drives	Below 275
ESDI	300 Mbyte	1 drive	Below 250
ESDI	300 Mbyte	2 drives	Below 350
SCSI	Any drive size		250+100*(total drives-1)

[Ref. 18:pp. 79-89]

2. Workstation Design

The next hardware component that should be designed are the user workstations. Individual workstations on the LAN are usually microcomputers from the same or compatible manufactures. "An important aspect of LANs that must be clearly understood is that in a microcomputer based LAN the actual processing is distributed out to the users' workstation." [Ref. 16:p. 16] Because a majority of the personnel computing is done at these intelligent workstations and at the same time they are nodes on an existing network, configuration is critical. It is also

complex and a majority of the specifications are presented with out explanation.

One area that warrants some investigation is the amount of memory required in each workstation. Resident in the workstation RAM are the three basic software file types: the network operating system, the disk operating system, and the application files. The amount of RAM utilized by both of the operating systems is a given prerequisite. The RAM needed by the application programs is the primary variable.

The workstation configuration, as with the server, should be driven by the applications software. However, due to the large number of parameters and possible combinations for a workstation configuration, the LAN Factor is impractical to employ. Instead, each station should be created according to the primary application to be run on that computer. In Table V the RAM required by the operating systems, network and disk, are already taken into account and thus do not appear as variables. Entering Table V with the primary application will yield the specifications necessary for any workstation to effectively and efficiently operate both as a stand alone and as an integral part of the system.

TABLE V

WORKSTATION CONFIGURATION

Specification	Application Type	
	Word Processing	Database
CPU type	80286	80286/80386
CPU speed	10-16 MHz	16-30 MHz
BIOS *	Compatible w/ network operating system	
RAM	1.1 Mbyte	1.1 Mbyte
Math coprocessor	No	No
Hard drive size *	0-40 Mbyte	10-40 Mbyte
Floppy drives	1.2 Mb; 5 1/4 inch + 1.44 Mb; 3 1/2 inch	
Keyboard type	Enhanced (101 Key)	
Monitor	Minimum EGA color	

* Basic Input Output System
** IEEE ST-506

Table V Continued

Specification	Application Type	
	Spread sheet	CAD/CAE
CPU type	80286/80386	80386
CPU speed	16-30 MHz	20-30 MHz
BIOS	Compatible w/ network operating system	
RAM	1.1-3 Mbyte	4-6 Mbyte
Math coprocessor	Yes *	Yes *
Hard drive size	0-40 Mbyte	130-260 Mbyte
Floppy drives	1.2 Mb; 5 1/4 inch + 1.44 Mb; 3 1/2 inch	
Keyboard type	Enhanced (101 Key)	
Monitor	Minimum EGA color	

* Coprocessor speed must match the CPU speed

Table V Continued

Specification	Application Type	
	BEST	
CPU type	80286/80386	
CPU speed	12-33 MHz	
BIOS	Compatible w/ network operating system	
RAM	1.1 Mbyte	
Math coprocessor	No	
Hard drive size	0-40 Mbyte	
Floppy drives	1.2 Mb; 5 1/4 inch + 1.44 Mb; 3 1/2 inch	
Keyboard type	Enhanced (101 Key)	
Monitor	Minimum EGA color	

[Ref. 1] [Ref. 16] [Ref. 19] [Ref.20] [Ref. 21][3]

A properly designed workstation will be able to function efficiently as a stand alone processor accessing the server minimally. At the same time it will have the proper configuration and specifications to efficiently access and communicate with the server when necessary. One of the

[3]The information contained in Table V was extracted primarily from the listed references and is supplemented with information collected during the case study and from the thesis co-advisor's and author's personal experiences.

fundamental reasons for a workstation to exchange data with the server is to gain access to shared peripherals.

3. Peripheral Selection

"Resource sharing is the greatest advantage currently offered by local area networking." [Ref. 1:p. C11-010-114] The sharing of hardware such as disks, printers, and communications connections distributes the cost of that hardware among all participating devices. This is especially advantageous when the cost of the peripherals is prohibitive, such as is the case with laser printers, graphics plotters, and facsimile machines. It is very difficult for any one organization to justify the purchase of more than one of these devices. Additionally, because most peripherals are some form of output device there use is sporadic at best. The sharing of these output devices greatly increases the service to idle time ratio.

Because these output devices are to be exploited by all of the users it is important that some thought be given to their location. The devices should be centrally located or if they are for specific applications located near the primary users.

Of particular importance in the PWD arena is the placement of the graphics plotter used by the engineers for Computer Aided Design and Computer Aided Engineering (CAD/CAE) applications. Due to the large files manipulated and produced by CAD/CAE it is recommended that the associated plotter not be a

attached to the server. In addition, the designer should insure the CAD/CAE workstation is configured has indicated in Table V to allow for stand alone operation. If the graphics plotter is a shared device or if the CAD/CAE workstation is configured so that its processes are highly server interactive the system will become bogged down and response time will decrease exponentially. [Ref.17:p. MC41-050-403]

Conveniently and correctly placed equipment will go a long way in increasing the user friendliness of the LAN. The designers should review and plot these peripheral locations on the master blueprint. The sharing of software files and data also have their advantages.

Sharing software files, such as word processing packages, enhances security, since all of the attached devices use the same version, in fact the same master copy. Access to these files can be controlled by the network manager through the use of the network operating system. Additionally, since only one copy is required this further reduces the need for individual storage devices.

Sharing data, such as database and spread sheet applications, increases the reliability of the information. Modifications and updates to the data made by one user are immediately available to all other users. The final hardware

components to be investigated in the hardware section are the interface devices.

4. External Interface Considerations

"Used properly, the LAN can provide a common interface for a diversity of otherwise incompatible equipment, serving as the backbone of an orderly hierarchy of computing functions extending from the mainframe to the desktop." [Ref. 1:p. C11-010-107] To accomplish the desired interconnection between external information systems, various external interfaces are employed. Internal interfaces which are utilized within a network to connect devices will be examined in the cable plant section. Before investigating the various external interfaces and a few security issues, Table VI presents a series of questions that should be answered prior attempting any communications between systems.

The designers should analyze and compile the communications section of the Division Analysis Sheet in order to answer the interface question thoroughly. The interconnection of networks is complicated and requires that the designer have a firm understanding of the systems already in place prior to beginning any modifications or expansions. Due to the complexity involved in this area it can not be over emphasized that automation is not always the answer to communications problems. Unless automating the system increases productivity or reduces

paper work establishing or maintaining a manual system is preferable.

TABLE VI

EXTERNAL INTERFACE QUESTIONS

1. What, where, and when is the present information flow?
2. How does the information flow?
   a. If information flow is manual, does it need to be automated?
   b. If information flow is automated, does it need improvement or refinement?
3. How sensitive is the information to be exchanged?
4. What is the best hardware/software combination to effectively make the connection?

"The details of interconnection matter, the details must be correct and are inherently complex. A 'powerful', 'intelligent' system can lead to the well documented problems of 'over automation', causing the user to be a passive observer of

operations, no longer in control of either what operations take place, or how they are done." [Ref. 15:p. 49] However, there are areas where the careful implementation of communications hardware and software will greatly enhance operations. Once the designer has a firm grasp of the present communications systems, there are three basic external interfaces: modems, bridges, and gateways.

a. *Modems*

Information can be transmitted between systems through the use of a modem. A majority of intra-network communications are accomplished through the use of discrete digital data signals transmitted across a medium, typically coaxial cable. On the other hand, the transmission of information between networks is through existing telephone wiring. The technology employed by the phone system is a continuous analog signal. A modem, contraction for modulate and demodulate, is a conversion device to allow two digital networks to exchange data through the use of an analog link. "Modems are installed in pairs at each end of an analog communications line. The modem at the transmitting end modulates digital signals received locally from a computer or terminal; the modem at the receiving end demodulates the incoming signal, converting it back to its original format (digital), and passes it to the destination business machine." [Ref. 22:p. C04-100-114] Modems

are frequently utilized to transmit data over a long distance or when the frequency, security, and accuracy of the information passed does not justify the costs of installing dedicated cabling.

b. Bridges

A bridge is the hardware and software necessary for two networks using the same or similar architectures to communicate. For example two Ethernet based networks communicate through the use of a bridge. The hardware part of the bridge is simply a PC on the network where the bridging software resides and through which all messages for other networks must pass. The primary functions of message addressing and routing are performed by the bridging software. All messages are passed through the bridge. If the message is addressed to a node on another network the bridge attaches the appropriate network address and routes the message through the correct cabling. Bridges are typically used in organizations where two or more functional areas are individually networked and there exists a requirement to exchange information between networks. Bridges can also be used to isolate traffic to workgroups in the same physical area, reducing unnecessary traffic across the entire network. Not all networks use the same architecture. In these cases gateways are used to communicate.

c. Gateways

A gateway is the hardware and software necessary to make two architecturally different networks communicate with one another. For example a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) "Ethernet" based network communicates with a Token Ring based network through the use of a gateway. "A gateway is a conceptual or logical network station that performs protocol-conversion, addressing and routing operations across a wide spectrum of communications function layers." [Ref. 22:p. C04-100-111] Contrasted with the bridge, the gateway performs the additional function of protocol conversion. Due to the high costs of adding additional terminals to large mainframes and the need to access and manipulate mainframe information in a user friendly environment, many corporations are using gateways to link their microcomputer networks to mainframe systems.

d. Security

Security is always an issue when data is transmitted across an unprotected medium. "At the current state of the art, lack of data security is arguably the biggest disadvantage of a local area network." [Ref. 1:p. C11-010-115] Some vendors are beginning to introduce data encryption to protect transmitted data, however, this only prevents the use of the intercepted data. A relatively unsophisticated intruder can

still destroy data fairly easily. [Ref. 1:p. C11-010-116] As a result, for the time being, as is the case with most communications networks, LANs remain relatively insecure.

However, while it is true that heavy security measures may not be needed, just to protect the system and the users from mechanical and personnel errors, some measure of security will be required. The use of IDs and passwords to limit access to various hardware and software should be sufficient. "If the reasons for installing a LAN are at all important to the organization, then some attention to security features is required; and if the data is important, then consideration should be given to security issues." [Ref. 16:p. 71]

G. DEFINE CABLE PLANT

> As much as chaos is part of the natural order, we must fight randomness. We must bring order to cabling systems. And while cabling is about as glamorous as plumbing, it is the very backbone of the company's ability to communicate. [Ref. 23:p. 86]

The cable plant is the physical media interconnecting nodes on a network and although it is arguably the most critical aspect of the entire system it often receives the least amount of attention and funding. The electronic infrastructure, as it is sometimes called, requires special attention from the designers. This section is divided in two parts. First, some basic guidelines, common pitfalls, and helpful suggestions are

presented. Second, a method for structuring the cable plant is tendered.

The design and implementation of a network infrastructure is a major undertaking. The time and money invested in such a project are substantial. As such, it is essential that the plant be planned and created properly. Over the lifetime of a network, the total cost of an improperly designed cable plant will increase due to a number of reasons. First and foremost, the costs of any modifications are much greater in a haphazardly designed plant than in a correctly and carefully designed one. This is particularly true if different types of transmission media, such as twisted pair wire, coaxial cable, and optical fiber, are used in the same network.

Secondly, trouble shooting a poorly designed network is extremely difficult. Poor design usually connotes poor documentation, making error detection, isolation, and correction a laborious task. "Generally cable plants that have evolved over a number of years are not documented properly, just finding the correct cable to test could take hours. ... it's often cheaper to install a new cable than trace an old one to determine if it is defective." [Ref. 23:p. 89]

Adherence to two basic principles should alleviate a majority of the problems typically encountered with electronic infrastructures. First, standardize on a transmission media. In

today's technology the common choices are twisted pair wire, coaxial cable, and optical fiber. Standard media allows the telecommunications outlets (connections to the network) to be standardized also. This enables, when necessary, devices to be easily moved from one location to another without the need for cable additions or modifications. This flexibility is aided through the use of devices called baluns. "These devices, which are nothing more than impedance matching transformers, can be set to match the transmission requires of equipment to the transmission characteristics of the media. When using baluns, one type of media can support numerous types of terminal devices." [Ref. 23:p. 86]

Second, even in a well designed state-of-the-art cabling system, plan for change. The need to retrofit can arise from any combination of a number of reasons: architectural changes, expansion requirements, or technology advancements in the telecommunications industry. Indeed, recent studies by major systems vendors have indicated that cabling systems, on the average, need to be augmented or replaced every six to eight years. [Ref. 23:p. 88] For this reason it is essential that the installation of conduits, risers, cable trays, and telecommunications closets be properly located, sized and constructed to allow for maximum flexibility. This includes the foresight to pull extra cabling for future growth. "Most

analysts and consultants recommend that as many wires pairs as possible be pulled when installing a network. The extra cost for additional wire is minuscule when compared to the labor costs of having someone come out and pull the cable as an afterthought." [Ref. 17:p. MC41-050-402]

Following these procedures can greatly decrease the life time costs of any network. However, the up front expense of implementing a well designed cable plant, as opposed to an infrastructure that merely satisfies the minimum requirements, deters many designers and system administrators. This type of shortsightedness can be very expensive in the long run. [Ref. 1:p. C11-010-116]

1. **Structured Cabling**

A properly designed cabling system should be independent of the number and type devices connected to it. This section presents a structured cabling configuration. The configuration presented is the standard in the telecommunications industry and should be used regardless of the network's logical configuration. [Ref. 23:p. 88] The structure can be broken into two levels, the horizontal subsystem and the vertical subsystem. The horizontal subsystem covers the connections from the user outlets to the telecommunications closets, while the vertical subsystem or backbone entails the media between the telecommunications closets and the distribution frame (see Figure

3.2). The configuration is a physical star, but through the proper use of the telecommunications closet has the ability to be configured into almost any logical topology. [Ref. 18] All connections in the configuration are identical and located centrally in the telecommunications closets. These standardized

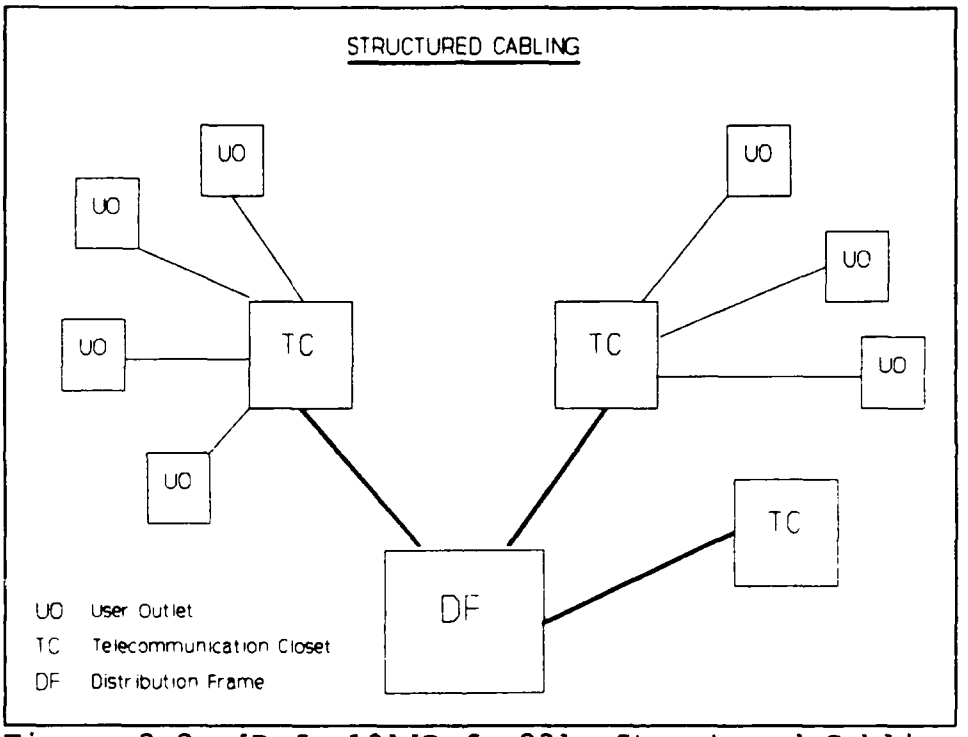


Figure 3.2 [Ref. 18][Ref. 23] Structured Cabling

interfaces provide the flexibility to interconnect and retrofit the subsystems as required.

The design of the horizontal subsystem is perhaps the most difficult portion of the cable plant due to the various transmission media and their characteristics. It is beyond the

scope of this study to investigate the alternatives as they all have their advantages and disadvantages depending on the particular environment and application. WESTDIV is presently supporting the CSMA/CD IEEE 802.3 "Ethernet" technology. "Of the standard networks available, the most widely deployed and supported system is certainly Ethernet (802.3)." [Ref. 16:p. 112] The 802.3 standards are very flexible and allow for a number of media to be utilized. There are three commonly used cabling technologies used under the 802.3 umbrella and supported by WESTDIV, standard or thick Ethernet (10base5), thin Ethernet or "cheapernet" (10base2), and unshielded twisted-pair (10baseT). Some basic characteristics of these 802.3 technologies are presented in Table VII.

Twisted-pair is intended for low-cost, low-performance requirements. It supports fewer workstations at lower speeds than the coaxial media. However, the lower cost and ease of installation make it well suited for some more elementary applications.

The thin, lightweight, flexible and inexpensive Cheapernet is ideal for connecting devices in the horizontal subsystem. The maximum distance of 200 meters, between the user outlet and the telecommunications closet, usually does not cause a problem.

TABLE VII

IEEE 802.3 SPECIFICATIONS

	Standard Ethernet 10base5	Cheapernet 10base2	Twisted-Pair 10baseT
Transmission Speed	10 Mbps	10 Mbps	1 Mbps
Media	Thick Coaxial Cable	Thin Coaxial Cable	Unshielded Twisted-Pair
Maximum Distance	500 Meters	200 Meters	1 km
Logical Topology	Bus	Bus	Bus

[Ref. 24:pp. 331-370] [Ref. 16:p. 77]

The vertical subsystem, or backbone, provides connectivity between the telecommunications closets and the distribution frame. The media typically used in this subsystem is Thick Ethernet. Thick Ethernet is ideal for transmitting large amounts of data rapidly over long distances (up to 500 meters). The vertical subsystem typically runs between buildings to and from a central distribution point and thus is exposed to a variety of environmental conditions. To avoid physical and electrical problems, the designer should insure proper grounding and bounding procedures are followed ("rodents just love high density polyethylene cable jackets" [Ref. 23:p. 102]).

Finally, the need to maintain accurate documentation can not be overemphasized. Use of the structured cabling method described should provide a sound network base, but eventually retrofit will become necessary. "Without up-to-date records of cable types, uses and cable availability, the execution of adds, moves, and changes is a nightmare and troubleshooting network problems is nearly as bad." [Ref. 23:p. 104] However, if the electronic infrastructure is properly planned, structured, installed, maintained and documented, the inherently high costs of cable plants can be drastically reduced.

H. EVALUATE ALTERNATIVES

There's always more than one way to implement the objectives of an information system. [Ref. 8:p. 199] The purpose of evaluating alternatives is to identify the best solution given the user's requirements. The evaluation process, as is indicated in Figure 3.1, should be continuous throughout the design phase, indeed throughout the entire WESTDIV Local Area Network Assistance Visit. Alternatives should be evaluated by their ability to fulfill the design objectives outlined earlier in Table I. The available alternatives will be constantly effected by the entrance of new information into the equation (Figure 3.1). The new information should be analyzed and new alternatives designed.

The designers should evaluate the impact of particular solutions on the users. In many cases, it may be a computer-based system is inappropriate and a manual system would be just as efficient and at the same time more user friendly.

It is important to examine as many alternatives as time permits. The resulting Requirements Evaluation Report document represents a major commitment of funds, personnel, and time and is the result of much tedious analysis and design efforts. Chapter IV presents an outline of the information that should be included in the Requirements Evaluation Report.

"The design step is a critical activity that demands careful attention to short and long term information service requirements as well as ensuring the delivery of a reliable service." [Ref. 25:p. 84] Use of the methodology presented in this chapter, along with careful planning and execution should allow the designer to achieve the desired objectives.

IV. SYSTEM REPORT

A. INTRODUCTION

Chapter II presented design objectives and outlined a method for achieving these objectives. In this chapter a review of the WESTDIV deliverable, the Requirements Evaluation Report, is conducted.

The purpose of the RER is to provide the PWO with LAN guidance during the planning stages. Additionally, the information contained in the RER will allow the PWO to make more informed decisions and work more effectively with vendors during the implementation phase. The RER should be presented to the PWO and used as a guide for the PWO outbrief.

Upon completion of the design phase the designers should posses a detailed list of all the software, hardware and communications equipment needed to properly implement the desired system. The idea is to communicate this information, through the RER, on a level and in a manner that is most useful to the PWO.

This chapter provides an outline of the RER and some basic information which should be contained in each section. The RER is divided into four sections with three appendices. The four sections are: executive summary, research methodology, recommendations, and conclusions. The three appendices are:

system components, component specifications, and equipment distribution.

B. REQUIREMENTS EVALUATION REPORT

1. Executive Summary

The executive summary should be no longer than one page in length and provide the PWO with an overview of the entire WESTDIV Local Area Network Assistance Visit. The summary should be broken into four paragraphs: visit purpose, visit scope, research methodology, and conclusions.

In presenting the visit purpose, the BEST portion of PWMA and its importance to the PWD should be reviewed. Provide the latest information on when the BEST software modules will be converted to run on a LAN. Finally, reiterate that due to the increasing cost and decreasing support of the Honeywell DPS/6 75 minicomputer, migration to a microcomputer based LAN is highly recommended.

To begin the visit scope paragraph, the PWO should be reminded the visit was initiated, through an Engineering Service Request, by the PWD. In response WESTDIV conducted a study to design a LAN that will cost effectively provide the Public Works Officer with a flexible and expandable information system.

A brief explanation of the research methodology used provides the PWO with the assurance that the information

contained in the RER is valuable. An overview of the analysis and design methodologies should suffice.

Finally, in the conclusion paragraph, a synopsis of the designer's observations and recommendations should be provided. A statement concerning the feasibility or infeasibility of network installation at the particular facility is appropriate at this point. The paragraph should conclude with a statement assuring the PWD that LAN implementation can be completed effectively and efficiently within the existing information systems framework.

2. Research Methodology

The object of the research methodology section is to provide an outline of the steps taken to reach the final LAN design. The section, if written correctly, should provide any readers with the assurance that the information contained in the RER is credible. Additionally, at a future date, a reader should be able to identify the areas covered and procedures utilized during the design to ascertain the present validity and utility of the study.

The presentation of the analysis and design methodology figures, from chapters II and III respectively, along with a brief explanation of each should be provided. Also, any additional measures taken during the specific study should be

indicated. Note, don't underestimate the importance of this section. The idea is to establish the credibility of the RER. Without proper documentation the information contained in the RER is suspect.

3. Recommendations

The recommendations section is highly dependent on the specific PW facility. However, in general at a minimum, there are two areas that should be included: a brief description of the status quo and recommended alternatives.

A quick outline of the present PWMA procedures and the equipment utilized gives the reader a ready reference to compare the alternatives against. Normally it is appropriate to provide the reader with at least three alternatives. The first alternative is always the status quo. Pros and cons for this alternatives should be provided.

Two more options along with their associated advantages and disadvantages should be reviewed. Always put the recommended alternative last and insure the supporting documentation is solid.

4. Conclusions

In the conclusion the writer should further emphasize the advantages of the recommended alternative and, assuming the

recommended alternative is a LAN, provide a quick advertisement for microcomputer based networks.

In situations where it appears that the designers recommendations will be adhered to, the writer should assume the recommended solution will be adopted and provide some guidance as to how and when the system should be implemented. Because restrictions on funds sometimes prohibit purchasing the entire system at one time, this guidance is usually in the form of a phased implementation plan. This is normally accomplished by breaking the system into separate functional components. The size and number of the components and resulting phases is dictated by the particular PWD status.

Finally, a statement expressing appreciation for the PW cooperation and the desire to be of further service if the need arises is appropriate.

5. **Appendices**

The appendices of the RER provide all of the technical information required to actually begin implementation of a LAN. The three appendices are: system components, component specifications, and equipment distribution. The system components appendix should begin with a brief explanation of the functions of the major components of the network. The components that should be covered are: network operating system, network

server, server storage subsystems, workstations, cable plant, network printers, and communication devices. Following these descriptions the writer should provide the actual technical specifications for each of the components above. This information can be obtained from various General Services Administration (GSA) schedule contracts. Copies of the GSA schedules used should also be included in this appendix.

The system specifications appendix provides the PWO with a detailed shopping list of all the components necessary to complete the system. This list should be broken into the appropriate sections if a phased implementation plan is to be utilized. The list should contain the number of units required, unit price, total prices, and applicable specifications for all of the software, hardware, and communications equipment.

Finally, the equipment distribution appendix should give the location of all of the hardware components and an outline of the cable plant. The appendix should contain a copy of the designers master blue print showing all of the pertinent data.

V. CONCLUSION

A. SUMMARY

The purpose of this study was, through the application of both academic and practical procedures, to develop a comprehensive guide for establishing a microcomputer based LAN and to stimulate interest for further study in this area. The synthesis of analysis and design models, theory, case studies and practical experiences provided a sound bases for this study.

Following the introductory chapter, analysis objectives and a plan for achieving these objectives were outlined in chapter II. The analysis plan, through the use of personal interviews, information forms, and structured walkthroughs, provided the analysts with a step wise procedure leading to well defined present and future systems requirements. On these requirements the network design was based.

In chapter III design objectives were presented and, despite the elusive concept of a correct or best design for a given system, a design methodology was tendered. Weighting of the user applications provided the 'LAN Factor' used to determine the server components. The workstations were also configured according to the user programs. A structured method for establishing an effective and cost efficient cable plant was

presented. Finally, chapter IV reviewed the essential parts of the Requirements Evaluation Report.

B. CONCLUSIONS

The analysis and design of microcomputer based local area networks is as highly dynamic as the LAN industry itself. The continual advent of new and improved technologies in this field insures that there is no single, all encompassing technique specifically for the analysis and design of networks. Likewise, while there are multiple system designs that will support a given installation, no one configuration will provide all of the needed functionality.

> ...the implementation of a local area network can be a radical and expensive step - and hard to justify... A radical innovation must offer radical benefits. A LAN can simplify and streamline current procedures and can offer benefits not available, or simply too expensive, with conventional communication techniques. [Ref. 1:p. C11-010-107]

Through the use of both academic and practical resources, networks can be designed to meet a majority of an organizations needs and at the same time be economically feasible to implement, manage, and maintain.

APPENDIX A

INTRODUCTION LETTER

WESTDIV Letterhead

From: Commanding Officer, Western Division, Naval Facilities Engineering Command (WESTDIV)
To: Public Works Officer,_____

Subj: WESTDIV Local Area Network Assistance Visit

Encl: Information Systems Review and Preparation Sheet

1. In response to the Engineering Service Request of _____, the purpose of this letter is to prepare for the impending Public Works Management Automation (PWMA) Local Area Network (LAN) assistance visit.

2. The proposed dates are _____ to _____.

3. The proposed assistance team members are _____ and _____.

4. Please forward the enclosure to your Automated Data Processing Representative (ADP Rep) for action.

5. The following background information is provided.

PWMA is presently a function of Base Engineering Support, Technical (BEST) Maintenance Control Subsystem. The increased number of BEST system users and large databases has resulted in a degradation of the system response time. According to NAVFAC ltr 5200 16b of 6 Mar 89, to solve this problem, "There is an increasing interest by activities in converting to networked microcomputer systems as opposed to minicomputer upgrades." The letter continues, "Given limited resources and potential pay-back of investment, NAVFAC has opted not to sponsor an open ended delivery order contract for system (Honeywell) upgrades." In response to this decision WESTDIV is beginning a project to provide the analysis and design criteria to replace all the Honeywell minicomputers with microcomputer based LANs.

The assistance visit, entailing both analysis and design, lasts two weeks. At the conclusion of the survey the assistance team will present the Public Works Officer with a Requirements Evaluation Report including research methodology, findings, component and design recommendations, and hardware and software specifications.

6. If there are any questions please call _____ at _____.

signature

APPENDIX B

INFORMATION SYSTEMS REVIEW AND PREPARATION SHEET

The following information and preparation are required by the survey team prior to the site visit to ensure a technical evaluation is feasible.

SECTION 1 - Preparation Schedule

The Automated Data Processing representative is asked to adhere to the following schedule:

One Week from Receipt -

1. Please call the EFD at Av 859-7531 or comm (415)877-7531 and ask for _____ or _____.
2. Be prepared to establish site visit dates.
3. Take this opportunity to ask any initial questions concerning this sheet.

Three Weeks Prior to Visit -

1. A member of your survey team will make contact with you.
2. Be prepared to ask any questions that have developed while completing this sheet.

Two Weeks Prior to Visit -

1. Please mail SECTION 2 of the Information Systems and Preparation Sheet (excluding any blueprint documents) to:

Commanding Officer
Attn: _____ and _____
Code 1615
WESTERN Division Naval Facilities
Engineering Command
P.O. Box 727
San Bruno, California 94066

One Week Prior to Visit -

1. Please ensure the necessary preparations outlined in SECTION 3 of this sheet have been completed.

SECTION 2 - Preliminary Information

I. Base Information

A. Base Map (indicating building locations)

B. Individual Building Drawings (to scale)

C. Base Cabling Diagrams

II. Base Automated Data Processing (ADP) Information

A. Base ADP Point of Contact

B. Base Wide Automation Plan (if in existence)

C. Existing External Systems (any system not in PW)

III. Existing PW ADP Systems

A. System Equipment (number systems 1-?)

1. CPU Configuration

a. Random Access Memory (RAM)

b. Disk Storage (type and amount)

c. Peripheral Devices (brand names)

2. Operating System(s)

3. Applications Software (brand names)

4. Limitations and/or Problems

B. System Utilization (match with system number above)

1. Primary utilization (i.e. word processing, database,CAD,...)

2. Frequency of System Use (hours/day)

3. Communication Requirements (where does the raw data come from and the processed information go to)

C. Annual Cost per System (match with system number above)

1. Software Cost

2. Hardware Cost

3. Consumable Cost

IV. Proposed PW ADP Systems

A. Status (i.e. on order, approved awaiting funding, etc...)

B. Next Event Date (i.e arrival date, order date, etc...)

C. System Equipment (number systems 1-?)

1. CPU Configuration

a. Random Access Memory (RAM)

b. Disk Storage (type and amount)

c. Peripheral Devices (brand names)

2. Operating System(s)

3. Applications Software (brand names)

D. System Utilization (match with system number above)

1. Projected utilization (i.e. word processing, database,CAD,...)

2. Communication Requirements (where will the raw data come from and the processed information go to)

E. Purchase Cost per System (match with system number above)

1. Software Cost

2. Hardware Cost

SECTION 3 - Site Preparation

In preparation it is essential a conference room is reserved for the two week period. The room will be utilized for interviews and as a central work location. The room must accommodate at least eight people. Additionally, a conference style table, large enough to spread blueprints on, is required.

It would be most helpful if a telephone were available in the conference room.

Please schedule an in-brief with the PWO and notify the APWO so he may be in attendance. Sometime during day one, following the PWO in-brief, arrange for an in-brief with the Department division heads. Please ensure the PWO is available during this in-brief in the event he would like to attend. A fifteen and twenty minute time slots, respectively, for each of the in-briefs on the morning of day one will be sufficient. Finally, during the first three days, please schedule a one hour meeting with each of the division heads individually.

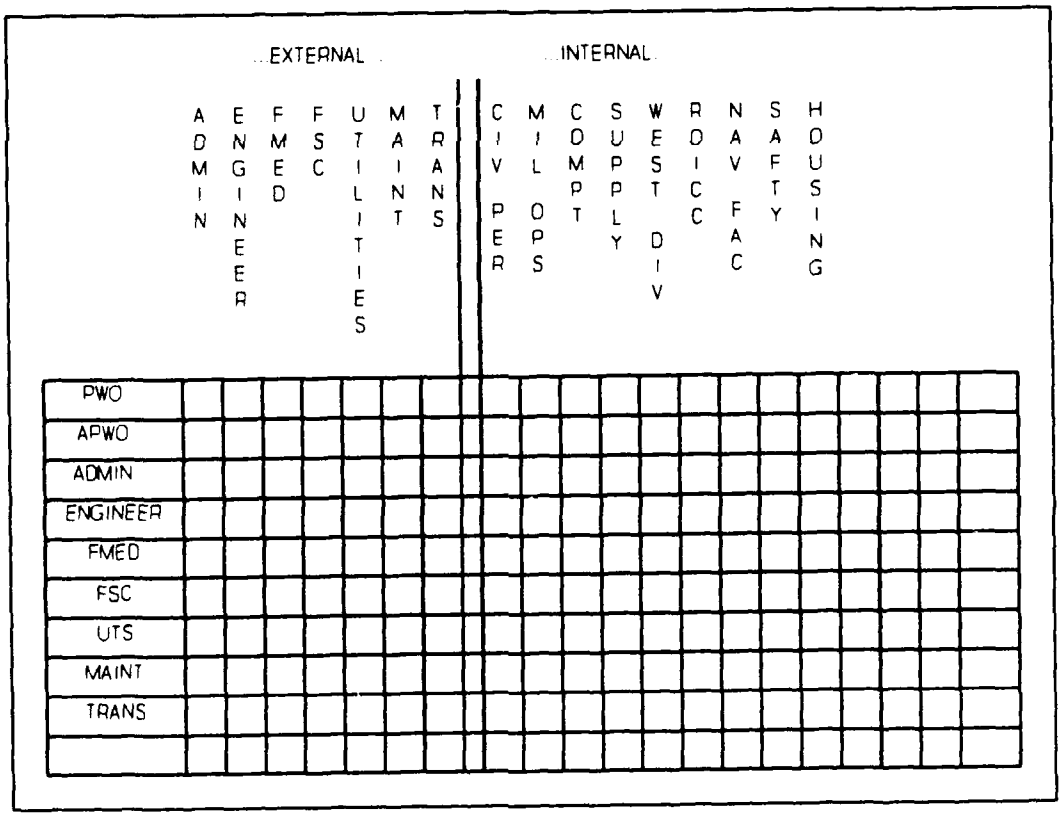
If there are any questions please do not hesitate to call.

THANK YOU FOR YOUR COOPERATION IN COMPLETING THIS SHEET

APPENDIX C

INFORMATION EXCHANGE SHEET

A. Please place an X in any box where there is an exchange of information between your division and any of the internal and/or external units. The information exchange can be either verbal, written, or electronic.



APPENDIX D

DIVISION ANALYSIS SHEET

Division: _____
POC: _____

Phone: _____

Present Staff Size: ____
Anticipated Staff Change: ____
Total: ____

Present Function: _____
_____
Future Function: _____
_____

# of ADP Equipment Users: ____

Primary Applications: _____
_____

HARDWARE

	Existing Quantity & Type	Required/ Desired
Honeywell Terminals	___ _____	_____
Microcomputers		
8088/XT	___ _____	_____
80286/AT	___ _____	_____
80386	___ _____	_____
68000/Apple	___ _____	_____
Printers	___ _____	_____
Plotters	___ _____	_____
Other	___ _____	_____

Hardware Comments: _____
_____
_____

SOFTWARE

	Existing Quantity & Type	Required/ Desired
Database	___ _____	_____
Word Processor	___ _____	_____
Spreadsheet	___ _____	_____
Graphics	___ _____	_____
CAD/CAM	___ _____	_____

Software Comments: _____

_____

_____ _____

COMMUNICATION

Application # 1

Interface Organization: _____
Location: _____
POC: _____ Phone: _____

Does a functional connection exist? _____
Transaction Name: _____
Frequency of Transaction: _____
Number of Concurrent Sessions: _____
Problems/Peculiarities: _____
_____

Application # 2

Interface Organization: _____
Location: _____
POC: _____ Phone: _____

Does a functional connection exist? _____
Transaction Name: _____
Frequency of Transaction: _____
Number of Concurrent Sessions: _____
Problems/Peculiarities: _____
_____

Application # 3

Interface Organization:_____
Location:_____
POC:_____ Phone:_____

Does a functional connection exist?_____
Transaction Name:_____
Frequency of Transaction:_____
Number of Concurrent Sessions:_____
Problems/Peculiarities:_____
_____

	App #	Existing Quantity & Type	Required/ Desired
Honeywell	_____	___ _____	_____
	_____	___ _____	_____
Manual	_____	___ _____	_____
	_____	___ _____	_____
Modems	_____	___ _____	_____
Gateways	_____	___ _____	_____
Routers	_____	___ _____	_____
Bridges	_____	___ _____	_____
Emulation	_____	___ _____	_____

Communication Comments:_____
_____
_____
_____

Final Comments:_____
_____
_____
_____
_____
_____

APPENDIX E

WALKTHROUGH ACTION LIST

1. Issue Raised: _____

_____

_____

_____

Reference: _____

Resolution: _____

_____

_____

_____

2. Issue Raised: _____

_____

_____

_____

Reference: _____

Resolution: _____

_____

_____

_____

3. Issue Raised: _____

_____

_____

_____

Reference: _____

Resolution: _____

_____

_____

_____

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